**University of Alberta**

# Natural Recovery versus Seeding on a Pipeline Right-of-Way in a Boreal Mixedwood Forest in Central Alberta

by

Brian Edmour Salisbury ©

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# Dedication

A thesis is a strange thing. It is one of the few tangible things that can be taken from "The MSc Experience". It represents the culmination of many things, but tells so little about how it came to be. It fails to tell about personal growth; it fails to tell about friendships gained; it fails to tell about sleepless nights; it fails to tell about beer at RATT; but most importantly it fails to tell about the people who helped the author succeed.

Those who know me well know that I am going out on a limb to write from my heart but here it goes.

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# Table of Contents

**I. Introduction** 1
  1. Background 1
  2. Revegetation Regulations for Pipelines 3
  3. Pipeline Reclamation 5
  4. Paradigm Shift 8
  5. The Boreal Forest 9
  6. Research Objectives 11
  7. Literature Cited 11

**II. Natural Recovery vs Seeding On A Pipeline Right-of-Way In The Central Mixedwood Boreal Forest Of Alberta** 14
  1. Introduction 14
  2. Research Objectives 16
  3. Materials and Methods 16
    3.1 Site Description 16
    3.2 Experimental Design and Treatments 18
    3.3 Field and Laboratory Measurements 19
      3.3.1 Soil 19
      3.3.2 Vegetation 21
    3.4 Statistical Analyses 21
  4. Results and Discussion 23
    4.1 Soils 23
      4.1.1 Physical Parameters 23
      4.1.2 Chemical Parameters 24
    4.2 Vegetation 25
      4.2.1 Mixedwood Forest 25
      4.2.2 Peatland 28
  5. Summary and Conclusions 29
  6. Literature Cited 30

**III. Effects Of Pipeline Installation On A Right-of-Way In The Central Mixedwood Boreal Forest Of Alberta** 53
  1. Introduction 53
  2. Research Objectives 54
  3. Materials and Methods 54
    3.1 Site Description 54
    3.2 Experimental Design and Treatments 56
    3.3 Field and Laboratory Measurements 57
      3.3.1 Soil 57
      3.3.2 Vegetation 59
    3.4 Statistical Analyses 59
  4. Results and Discussion 60

## Table of Contents (continued)

4.1 Soils 60
4.2 Vegetation 64
4.2.1 Mixedwood Forest 64
4.2.2 Peatland 67
5. Summary and Conclusions 68
6. Literature Cited 69

**IV. Synthesis 113**
1. Introduction 113
2. Research Objectives 113
3. Materials and Methods 115

# List of Tables

Table 2.1. Climate data for the Environment Canada weather station near Whitecourt, Alberta 34
Table 2.2. Soil physical parameters on the seeded and natural recovery treatments in the mixedwood site in 2003 35
Table 2.3. Soil chemical parameters on the seeded and natural recovery treatments in the mixedwood site in 2002 36
Table 2.4. Mean cover and standard deviation of species common to seeded and natural recovery treatments in the mixedwood site in 2002 38
Table 2.5. Mean cover and standard deviation of species found only on the seeded treatment in the mixedwood site in 2002 40
Table 2.6. Mean cover and standard deviation of species found only on the natural recovery treatment in the mixedwood site in 2002 42
Table 2.7. Summary of ground cover characteristics on the seeded and natural recovery treatments in the mixedwood site in 2002 44
Table 2.8. Mean cover of plant species common to both the topographic low and high treatments in the peatland site in 2002 45
Table 2.9. Mean live cover of plant species found only on the topographic high treatment in the peatland site in 2002 47
Table 2.10. Mean cover of plant species found only on the topographic low treatment in the peatland site in 2002 49
Table 2.11. Summary of ground cover characteristics on the topographic low and high treatments in the peatland site in 2002 50

Table 3.1 Climate data for the Environment Canada weather station near Whitecourt, Alberta 71
Table 3.2. Summary of soil parameters from the seeded treatment in the mixedwood site 72
Table 3.3. Summary of soil parameters from the natural recovery treatment in the mixedwood site 76
Table 3.4. Summary of vegetation parameters from the seeded and natural recovery treatment in the mixedwood site in 2002 80
Table 3.5. Mean cover of plant species by pipeline right-of-way zone in the seeded treatment in the mixedwood site in 2002 81
Table 3.6. Mean cover of plant species on the pipeline right-of-way zones of the natural recovery treatment in the mixedwood site in 2002 87
Table 3.7. Summary of key ground cover characteristics from the topographic low and high treatments in the peatland site in 2002 96
Table 3.8. Mean cover of plant species by pipeline right-of-way zones of the topographic low treatment in the peatland site in 2002 97
Table 3.9. Mean cover of plant species by pipeline right-of-way zone of the topographic high treatment in the peatland site in 2002 104

# List of Figures

Figure 2.1. Schematic of mainline pipeline mixedwood forest site ........ 51
Figure 2.2. Schematic of the lateral pipeline peatland site ........ 52

Figure 3.1. Schematic of mainline pipeline mixedwood forest site ........ 109
Figure 3.2. Schematic of the lateral pipeline peatland site ........ 110

# I. INTRODUCTION

## 1. Background

Alberta's boreal forest natural region is one of the lifelines of the province. Although the population of this region is relatively small, resource extraction and processing has become a multi-billion dollar business. Industry currently active in the boreal forest includes conventional oil and gas, oil sands mining, forestry, coal and peat mining and agriculture (Strong and Leggat 1992; Natural Resources Development 2003). Although an overall effect is not known, cumulative impacts such as land base fragmentation, deforestation and waterway disturbances, resulting directly or indirectly from resource development, are believed to be rapidly changing the ecosystem (MacKendrick et al. 2001). Furthermore, cumulative impacts may change plant community structure, function and composition as well as the community's ability to respond to environmental stresses (Kimmins 1997).

Much of the disturbance in the boreal forest has been caused by oil and gas exploration and development that has occurred since the 1940s (MacCrimmon and Laing 2000). By the end of 2002, Alberta was transected by 317,417 km of pipeline rights-of-way (RoW) (Alberta Energy and Utilities Board 2002). Despite the fact that a large and constantly increasing percentage of the pipeline RoW are located in the boreal forest natural region, relatively little research has been conducted on the overall effect on the ecosystem and possible remedies (MacFarlane 1999). Although it is not as expansive as the boreal forest natural region, there are portions of the adjacent foothills natural region that are under similar pressure from pipeline RoW development.

On June 15, 1999, Alliance Pipeline Limited Partnership began construction of a pipeline, now commonly referred to as The Alliance Pipeline. The Alliance Pipeline transports natural gas from northeastern British Columbia and northwestern Alberta to the American market around Chicago, Illinois (Alliance Pipeline 1999). The Canadian mainline component of this pipeline consists of a 339 km section of 1067 mm pipeline and a 1220 km section of 914 mm pipeline. The Canadian lateral pipeline system is made up of 698 km of pipeline ranging in size from 114 to 610 mm.

The long accepted practice in the pipeline industry has been to revegetate linear RoW disturbances using commercial non-native seed mixes, although more recently there has been a movement towards the use of native seed mixes. The non-native mixes present several benefits, the most important of which are predictable rapid establishment of vegetation and effective erosion control; in the past these factors have been required for successful pipeline reclamation (Kerr et al. 1993). Despite these benefits there has been renewed interest by both industry and government to study alternative methods of pipeline revegetation. This interest is part of a larger change in resource management philosophy that has recently occurred within industry.

In the past, revegetation criteria focused on establishing plant cover and were not as concerned with plant species selection or ecological succession. Invasive non-native species, such as *Agropyron cristatum* (L.) Gaerten (crested wheatgrass), are persistent where seeded and prevent establishment of native species (D'Antonio and Vitousek 1992). When invasive species are seeded on pipeline RoW, the resulting plant community is not similar to the adjacent plant community and has the potential to invade the native plant community. Due to the increasing frequency and size of projects, such as the Athabasca oil sands, the Alberta Pacific Forest Industries development, the Alliance Pipeline and the proposed Alaska Highway Pipeline, resource management philosophies have had to change over the past 20 years. Depending on perspective, either these changes have resulted in a greater understanding of the issues by the public, or changes in society's expectations have driven the changes in resource management. One of the places where this change in philosophy is showcased is Alberta's legislation surrounding environmental issues, particularly in the area of land reclamation.

Currently, there is growing interest in assessing and understanding the potential effectiveness of natural recovery as a reclamation technique. The use of natural recovery to reclaim linear disturbances such as pipelines could provide many benefits. Since natural recovery relies on recruitment from the soil seed bank and surrounding plant communities, it may be both an inexpensive and effective revegetation method. Recruitment from the relict seed bank and the surrounding plant community may more closely resemble the predisturbance and adjacent communities. Reliance on natural recovery could also eliminate the problems associated with aggressive seeded species invading the adjacent community. If soil handling and replacement was done correctly, plant species that establish during natural recovery may be better adapted to local climatic conditions, grazing stresses and nutrient regimes than seeded species. Pipelines also have a high edge to area ratio which makes them good candidates for natural recovery. Despite this interest and the potential benefits in using natural recovery, very little scientific research has been conducted, particularly in the boreal forest, to assess its effectiveness. Current reclamation practices focus on rapidly establishing vegetation to meet criteria and there has been little incentive for industry to implement new techniques.

## 2. Revegetation Regulations for Pipelines

Prior to 1963, revegetation of a RoW following pipeline construction was not a priority. There was no legislation directing the reclamation of industrial disturbances, therefore pipeline revegetation consisted of the sporadic seeding of agronomic forages, if pursued at all. From the seeding of *Agropyron cristatum* (L.) Gaertn on the prairies to pasture mixes in the forest, little consideration was given to the ecological integrity of the disturbed community. In 1963, Alberta introduced the Surface Reclamation Act, which set standards for site cleanup and recontouring and set a precedent for reclamation certificates. The Act changed in 1973 to the Land Surface Conservation and Reclamation Act, and was amended in 1978 and 1980, resulting in progressive changes towards preservation of the environment in Alberta. However, government soil conservation and pipeline construction publications, as recent as 1988, do not address revegetation (Alberta Environment 1985; Alberta Environment 1988).

Today, construction and reclamation of pipelines in much of Alberta's boreal forest is guided by the Public Lands Operational Handbook (Alberta Sustainable Resource Development 2003). This handbook is based on an earlier publication, Guide for Pipelines Pursuant to the Environmental Protection and Enhancement Act and Regulations (Alberta Environmental Protection 1994). The latter guide made three recommendations regarding revegetation of pipelines. These are discussing species selection, methods and rates of seeding and fertilizing with the landowner or manager; using native species or mixes that will allow the establishment of native species where required; and minimizing the introduction of weeds. In 2001, the Reclamation Assessment Criteria For Pipelines was produced and includes a detailed section on plant growth (density, cover, height and health) and species composition. This section also considers noxious and restricted weeds, the seeding of *Agropyron cristatum* and plant species composition as an indicator of soil quality. Of particular significance is the section that recognizes, and briefly discusses, the suitability of plants on the RoW based on land use and ecological function. The criteria also consider native plant encroachment and seral progression based on the goals of establishing native vegetation and diversity of composition.

In 2000, the Native Plant Revegetation Guidelines for Alberta were produced (Native Plant Working Group). This publication resulted in the mandatory use of native seed for the reclamation of public land in the green area. The most recent guidelines, Public Lands Operational Handbook (Alberta Sustainable Resource Development 2003), are much clearer and ecologically conscientious. This document contains a vegetation management section that outlines specific management objectives. Although this document does not prescribe seed mixes, it does recognize the need to address site specific conditions, proposed and future land use and design functionality, in addition to the requirement to use native seed for reclamation. This document notes the importance of using native species to revegetate areas within native plant communities. The most significant section from this document, which has a direct bearing on the research being done, is regarding natural recovery. The section outlines the benefits of using natural recovery as a method of revegetation. Natural recovery "maintains native ecosystem function and structure, provides a variety of ecological niches for other life forms, ensures that landscapes are aesthetically pleasing, and that revegetation blends into the surrounding landscapes, maintains genetic diversity and results in reduced soil erosion due to the superior soil-holding capability of many native species".

The acceptance by government of natural recovery as an appropriate revegetation tool was explicitly set forth in a Conservation and Reclamation Information Letter (Alberta Sustainable Resource Development 2002). This information letter provides guidance to operators working in the green area, who recognize the need for low impact construction and the use of native species, but are uncertain of the effectiveness of natural recovery. This document provides information on natural recovery, such as when it may be appropriate to use and how to evaluate the success of a natural recovery project. What this document does not provide is a detailed explanation of the underlying ecological principles that facilitate natural recovery and the factors that can influence its success.

## 3. Pipeline Reclamation

Since the first successful oil well was drilled in Leduc in 1947, Alberta has never looked back in its pursuit to extract and market the abundant oil and gas reserves found beneath the surface. In the years following that first success, oil and gas exploration and production in Alberta was primarily located in the southern half of the province. Steadily, exploration and production has moved north, and currently there are over 88,000 wells in the boreal forest natural region (Alberta Environmental Protection 1998). Nearly half of these wells are located in the central mixedwood subregion. In addition there are approximately 73,000 km of pipeline, with nearly 24,000 km in the central mixedwood subregion (Alberta Environmental Protection 1998).

In 1997, NOVA Gas Transmission Ltd. published the results of a 10 year rangeland revegetation monitoring study (Naeth et al. 1997). This study involved two 18 m wide lateral pipelines in southern Alberta. The Milo Lateral Pipeline spanned the dry mixed grass and mixed grass ecoregions, while the Porcupine Hills lateral spanned the aspen parkland, montane and fescue grasslands ecoregions. Treatments included seed type (native, non-native or none), grazing (present at known amount or none) and RoW treatment (work, trench, spoil and off RoW areas). Parameters measured included plant productivity, species composition, live cover, litter, bare ground and animal utilization. Differences in productivity arose from RoW treatments. Noteworthy was that forb productivity in response to disturbance was opposite to that of grasses. Pioneer forb species, from the seed bank of the disturbed site, increased in the short term but then decreased after a couple of years when the grasses established. After four years of growth, the spoil treatment had significantly higher productivity (2150 kg $ha^{-1}$) than the other three treatments, likely a result of the high abundance of *Agropyron smithii* Rydb. (western wheatgrass) and *Agropyron dasystachyum* (Hook.) Scribn. (northern wheatgrass).

Naeth et al. (1997) found that both native and non-native treatments had bare ground and litter levels approaching undisturbed conditions, although species composition was not. One of the main findings in this study was that in 1991, after five growing seasons, the sites seeded with non-native species still had significantly more bare ground than the control sites; this was not the case with the sites seeded to native species. Although the study was not designed specifically to evaluate natural recovery, the researchers did make some comparisons between seeded and unseeded treatments. Forb production was higher on seeded sites, while grass production was higher on unseeded sites. Herbaceous vegetation productivity was higher on unseeded sites. The most interesting finding, related to the current study, was that after five growing seasons the unseeded sites had greater total vegetation and litter cover and less bare ground than the seeded sites. Species composition differed between seeded and unseeded sites, with seeded sites dominated by *Agropyron dasystachyum* and *Artemisia frigida* Willd. (pasture sage), and the unseeded sites dominated by *Agropyron smithii* and *Artemisia frigida*.

Another study conducted on the Milo and Porcupine Hills lateral pipelines in 1998 also provides significant evidence that RoW areas affect vegetation establishment and success (Ostermann 2001). At the Milo sites, the trench had almost twice as much rhizomatous grass cover (native and non-native) as the undisturbed area. In comparison, tufted grass density was significantly higher on the undisturbed areas than on the trench at Milo. At both Milo and the Porcupine Hills, forb density was highest on the spoil. At Milo, significant differences in biomass occurred between the ungrazed trench, work and undisturbed areas. Researchers speculated that when a disturbance is small, native prairie might restore itself, as this research demonstrated there was an ample supply of propagules in the soil to establish vegetation on the RoW.

On a 20 m pipeline RoW near Cold Lake, Alberta, seeded treatments had 100% vegetation cover after two growing seasons, compared to less than 85% on the natural recovery treatments after four growing seasons (McCabe and Kennedy 1988). In 1983, treatment sites were grubbed with a brush rake and topsoil was salvaged and redistributed to minimize soil disturbance. Reclamation was conducted in fall 1983 using an agronomic seed mix consisting of *Festuca rubra* L. (creeping red fescue) (13.5 kg ha$^{-1}$), *Poa pratensis* L. (Kentucky bluegrass) (13.5 kg ha$^{-1}$), *Trifolium hybridum* L. (alsike clover) (3.5 kg ha$^{-1}$) and *Medicago sativa* L. (alfalfa) (3.5 kg ha$^{-1}$). Fertilizer (16-20-0) was broadcast at 160 kg ha$^{-1}$. The natural recovery treatment did not receive seed or fertilizer. After four growing seasons, 98% of the observed species on the seeded treatment were agronomic grasses and legumes, in particular *Festuca rubra* and

*Medicago sativa*. In contrast, the non-seeded treatment contained greater species diversity, including shrubs and forbs, but cover was lower in each of the four years. On the natural recovery treatment, 40% of the cover was shrubs and forbs and encroachment from the adjacent forest onto the RoW averaged 11.4 m after four growing seasons.

In a semi-arid woodland in New South Wales, Australia, a 12 year study was conducted on a natural gas pipeline RoW that was not seeded or fertilized (Walker and Koen 1995). The 24 m RoW was cleared of trees and shrubs and the excavated soil replaced in the trench, leaving a slight mound. Admixing was apparent and the surface layer was a mixture of soil, calcium carbonate, stones, rock fragments and occasionally boulders. The area was left to revegetate through natural invasion of species from adjacent areas. Sheep and wild animals grazed the RoW, with one sheep per 2 to 6 ha depending on rainfall and other management considerations. In total, 32 sites were assessed. The grass cover on trenched areas was lower than bladed and undisturbed areas, with perennial grasses increasing annually although cover remained lower than the undisturbed areas. Perennial grasses and forbs were scarce on the RoW compared to undisturbed areas and contributed to differences in species composition between the two areas. Species composition varied with rainfall on an annual basis. Overall, the effects of pipeline construction remained obvious 12 years after the disturbance.

In 1977 and 1978, pipeline revegetation was carried out in Jasper National Park (Wishart 1983). The focus of this research was on determining the effects of applying top dressings (10 cm acidic peat, 7.5 cm alkaline loamy sand and no top dressing), fertilizer (16-20-0-14) and seeding methods (raking, packing, mulching and broadcast seeding) on revegetation of harsh environments. Research was conducted on a pipeline near Celestine Lake Road that had been constructed in 1952 and had not been reclaimed. Three seed mixes were used at unspecified rates. Seed mix one included 20% *Poa alpina* L. (alpine bluegrass), 30% *Agropyron trachycaulum* (Link) Malte (slender wheatgrass), 30% *Elymus innovatus* Beal (hairy wild rye), 10% *Hedysarum mackenziei* Richards. (northern sweet vetch) and 10% *Juniperus horizontalis* Moench (creeping juniper). Seed mix two included 20% *Koeleria cristata* (Ledeb.) J.A. Schultes f. (June grass), 30% *Agropyron riparium* Scribner & J. G. Smith (streambank wheatgrass), 20% *Poa pratensis*, 10% *Agrostis stolonifera* L. (redtop), 10% *Astragalus* sp. L. (milk vetch) and 10% *Rosa acicularis* Lindl. (prickly rose). Seed mix three included 20% *Poa* *alpina*, 30% *Festuca saximontana* Rydb. (Rocky Mountain fescue), 30% *Agropyron* sp. (wheatgrass), 10% *Hedysarum alpinum* L. (alpine sweet vetch) and 10% *Elaeagnus commutata* Bernh. *ex* Rydb. (wolf willow). Fertilizer was key to establishing vegetation cover on low nutrient soils, especially when a non-nutrient rich top dressing was applied. Treated sites averaged 30% live cover in the second year of the study, while sites that had been recovering naturally for 25 years averaged 9.5% live cover. The high cover levels of the treated sites may decrease over time as the anthropogenic nutrient source decreases. Native species diversity was greater than non-native species diversity, although non-native species dominated the trench.

## 4. Paradigm Shift

From a regulatory perspective, reclaiming disturbed sites using natural recovery is becoming more acceptable. In Alberta, this is evidenced by the government's publication of a Conservation and Reclamation Information Letter that focuses on the assessment of sites that are reclaimed using natural recovery methods. Regulators are looking towards the potential of natural recovery due to increased interest in biodiversity, sustainability, native seed sources and reclamation timelines (Alberta Sustainable Resources Development 2002). Regulators are realizing that planting heavy crops to achieve an arbitrary level of cover (80% is commonly used) could slow invasion by native species and inhibit establishment of tree species. Furthermore, when disturbed sites are small or native seed is not available, plant communities derived from natural recovery will more likely closely resemble the adjacent plant community. Despite the potential benefits of natural recovery, the information letter noted several areas that need to be addressed prior to determining the appropriateness of natural recovery for a given site including project goals, risk of erosion, presence of viable plant propagules, risk of noxious weed invasion and site factors such as location and soil conditions.

Research on natural recovery in the boreal forest will provide insight into the reclamation of a pipeline RoW. If research demonstrates that natural recovery can provide a vegetation cover and species composition equivalent or closer to the undisturbed areas than a seeded area, the benefits to industry and government will be great. For industry, the cost of reclaiming an area will be lower as soil replacement will be the only reclamation required. Public lands will benefit by having a plant community that is consistent with the undisturbed adjacent areas without the concern of using seed sources that may contain noxious weed species and/or ecotypes that are not native to the ecoregion.

## 5. The Boreal Forest

The boreal forest comprises a significant component of the global landscape. The boreal forest is a region of mixedwood forest that stretches approximately 12,000 km across North America and Eurasia. This forest region is primarily found between 50° N and 70° N (Larsen 1980). A Russian term synonymous with boreal forest is taiga; although, historically taiga has referred to a coniferous forest without deciduous trees except for poplar and birch (Elliott-Fisk 1988). World wide, the boreal forest is estimated to cover 14 million $km^2$ (Bonan and Shugart 1989; Kasischke et al. 1995). Within Canada, there are approximately 3.2 million $km^2$ of boreal forest, making it Canada's largest ecosystem (Rowe 1972). Despite covering such a large tract of land, the diversity of trees within the boreal forest is quite small. World wide, the boreal forest is dominated by 12 tree species but in Canada that number drops to 5 species. These five dominant tree species are *Populus balsamifera* L. (balsam poplar), *Populus tremuloides* Michx. (trembling aspen), *Picea glauca* (Moench) Voss (white spruce), *Picea mariana* (Mill.) BSP. (black spruce) and *Betula papyrifera* Marsh. (white birch) (Gordon 1996).

Within the Canadian portion of the boreal forest there are changes in species composition that run along east-west and north-south gradients. These composition changes are primarily due to variation in precipitation and geology (Johnston et al. 1995). The eastern boreal forest lies over Canadian Shield whereas the western boreal forest lies over sedimentary and some metamorphic rock of the interior plains and western cordillera. Within Alberta, the boreal forest makes up approximately 350,000 $km^2$ of the landscape and extends from approximately 51° N to 60° N and spans the entire width of the province (Achuff 1994).

The RoW being studied has an index greater than 2690, calculated by multiplying the outer pipeline diameter by the length, and is classified as a class one pipeline. The study sites are located in a region of the province known as the green area, which encompasses most of the northern half of the province and some land in the mountains and foothills regions. The green area is forest dominated and not suitable for agricultural use except as grazing land (Alberta Sustainable Resource Development 2003). Conservation and reclamation approvals are not currently required in the green area of the province (Bruneski 2004); however, at the time of installation of the Alliance Pipeline an approval was required.

Two primary sources of literature are used to delineate ecological areas within Alberta. The first, Ecoregions of Alberta, was published by Strong and Leggat in 1981 and then updated in 1992. A second, Natural Regions and Subregions of Alberta, was written in 1992 by Achuff and has been adopted by most government branches in Alberta. Although these documents have subtle differences, their ecological boundaries are very similar, with ecoregions of an ecoprovince corresponding to subregions of a natural region. While a small component of this research took place in the lower foothills subregion of the foothills natural region, the focus of the study took place within the central mixedwood subregion of the boreal forest natural region. The central mixedwood subregion is analogous to the mid boreal mixedwood ecoregion defined by Strong and Leggat (1992).

The central mixedwood subregion is the largest subregion in the province and makes up an area of just over 150,000 km$^2$ (Achuff 1994). This subregion has a sub humid, continental climate with short cool summers and long cold winters. Soils are typically gray luvisols in upland sites and gleyed luvisols in lowland areas (Strong and Leggat 1992). Most frequently, *Populus tremuloides* is the dominant forest species, and can be found in pure and mixedwood stands. *Populus balsamifera* is also found in pure stands or mixed with *Populus tremuloides*. In older forests, these species give way to *Picea glauca* and eventually *Abies balsamea* (L.) Mill. (balsam fir), which could be considered the climax community for this environment (Strong and Leggat 1992). Research has also shown that large scale natural disturbances such as fire or insect infestation can have significant impacts on the structure and composition of forests (Henry and Swan 1974). Under natural conditions (no fire suppression), boreal forests are a product of disturbance and it has been suggested that multi directional succession occurs at one point in time (McCook 1994; Cook 1996). Due to a history of frequent fires in the boreal forest, it is relatively rare to see the suggested climax communities (Strong and Leggat 1992; Kenkal et al. 1997).

## 6. Research Objectives

The primary research objective was to compare the effectiveness of natural recovery and seeding on the reclamation of a pipeline RoW in the central mixedwood subregion of Alberta. Specific objectives were to:

1) Compare soil characteristics (total organic carbon, organic matter, nitrogen, phosphorus, potassium, electrical conductivity, pH, bulk density, penetration resistance and soil particle size distribution) on natural recovery and seeded pipeline RoW.
2) Compare plant community characteristics (bare ground, litter cover, canopy cover by species and species richness) on natural recovery and seeded pipeline RoW.
3) Compare treatment effects of pipeline RoW (forest, fringe, work, trench and spoil areas) on the above soil and vegetation variables.

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# II. NATURAL RECOVERY VS SEEDING ON A PIPELINE RIGHT-OF-WAY IN THE CENTRAL MIXEDWOOD BOREAL FOREST OF ALBERTA

## 1. Introduction

Natural recovery is a reclamation method of potential importance, as more sites require the use of native species, which can be very expensive, and of limited supply. The success of natural recovery is based on the ability of plants to establish from the seed and propagule bank on a disturbed site and the ability of plants to invade from adjacent communities. The potential contributions of the seed bank to revegetation have recently been recognized (Zhang et al. 2001; De Villiers et al. 2002). Although more research has been conducted on agricultural soils, there is a considerable and expanding pool of research on forest soils (Hills and Morris1992). Major considerations when evaluating the role a seed and propagule bank may play include age of the forest, level of canopy closure, latitude and elevation of the site and type of forest. Perhaps the single greatest hurdle facing natural recovery is time, as it is recognized that the time needed for plant communities to be restored through natural process can be decades or even centuries (Dobson et al. 1997).

As a forest ages, the seed and propagule bank is depleted (Roberts 1972), primarily as germination continues to occur even as seed input slows. Seed input decreases because as forests age, there is typically an associated closure of the canopy, which reduces the ability of some species to supply the seed and propagule bank. As the canopy closes, light becomes scarce and may be the main factor controlling species composition (Grime 1979; Lieffers et al. 1999). Under a closed canopy, plant growth and seed production conditions can be poor, and the most abundant species found in the seed and propagule bank are often those of off site species (Kellman 1974). These species are not the dominant late successional species but rather early to mid-successional species (Morin and Payette 1988; Morgan and Neuenschwander 1988). Over time there is also increased seed coat decay and predation (Granström 1986).

In the past, fires have been the main disturbance in the boreal forest. The type, intensity and frequency of fire have effects on the seed and propagule bank (Archibold 1989).

Fires that occur in the boreal forest are typically high intensity canopy fires (Heinselman 1981). Therefore, it is possible that the seed and propagule bank may not be disturbed. This is very different from anthropogenic disturbances such as well site or pipeline construction, where the seed bank can be significantly altered. One of the most detrimental effects of these anthropogenic disturbances on the seed bank is seed burial. If the duff material, which contains most seed and propagules, is not kept on the surface, the chance of seed germination and establishment is reduced (Kramer and Johnson 1987). Bringing material from depth to the surface lowers the number of seeds per area that could contribute to natural recovery (Granström 1986). An abundance of seed and propagule bank research identifies factors such as temperature, soil texture, soil moisture, seed burial depth, seed-soil contact, seed age, seed size, predation and light conditions as having influence on the productivity of the seed bank (Harper 1977; Hills and Morris 1992; Clark et al. 2000; Baskin and Baskin 2001). Much of this research suggests that the seed and propagule bank has potential to serve as an excellent source of plant materials for revegetation.

Plant invasion from adjacent undisturbed regions also contributes to the recolonization of disturbed sites. Invasion will occur when seeds or other plant propagules move from the undisturbed site to the disturbed site, germinate and establish. Invasion can occur through seed rain, erosion of seed on the ground or vegetative expansion. Factors that may affect this include wind direction, shape of the disturbance area, structure and composition of the adjacent community, animal populations present and soil conditions. The linear shape of a pipeline right-of-way (RoW) makes it conducive to invasion, as it has a very high edge to area ratio. This ratio reduces the distance that species must migrate from the edge to reach the center of the disturbance. Theoretically, on a pipeline that is 32 m wide and has vegetation on both sides, seed or plants only need to migrate 16 m to cover the site. In contrast, a lease site that is 100 x 100 m and is surrounded by vegetation, theoretically requires plants to migrate 50 m to cover the site. Therefore a narrow pipeline is a better candidate for revegetation through natural invasion than a lease site.

## 2. Research Objectives

The primary research objective was to compare the effectiveness of natural recovery and seeding on the reclamation of a pipeline RoW in the central mixedwood subregion of Alberta. Specific objectives were to:

1) Compare soil characteristics (total organic carbon, organic matter, nitrogen, phosphorus, potassium, electrical conductivity electrical conductivity, pH, bulk density, penetration resistance and soil particle size distribution) on natural recovery and seeded pipeline RoW.
2) Compare plant community characteristics (bare ground, litter cover, canopy cover by species and species richness) on natural recovery and seeded pipeline RoW.

## 3. Materials and Methods

### 3.1 Site Description

The study site is located in the central mixedwood subregion of the boreal forest natural region near Whitecourt, Alberta (Achuff 1994). Mean long term summer (April to September inclusive) temperature is 11.8 °C and mean long term winter (October to March inclusive) temperature is -6.0 °C. Mean total annual precipitation is 577.7 mm (Table 2.1). The dominant landforms of the area include ground moraine, hummocky moraine, aeolian dunes, sand outwash plains and organic deposits (Alberta Environmental Protection 1998). Reference vegetation of the area includes *Populus tremuloides* Michx (trembling aspen), *Picea mariana* Mill (black spruce) and *Picea glauca* Moench (white spruce) forests. Reference soils of the area are gray luvisols (Alberta Environmental Protection 1998).

The site is part of the Alliance Pipeline Ltd. mainline system starting at kilometer post (KP) 476.1 and ending at KP 479.5 of mainline spread 4W developed by The Alliance Pipeline Ltd. (Figure 2.1). The 3.4 km of pipeline crosses parts of NE/NW/SE 7-60-11, SW/SE 8-60-11 and NE 5-60-11, all W5M. The site is within a mature mixed stand of *Populus tremuloides*, *Picea glauca* and *Pinus contorta* Douglas (lodgepole pine) (Pockar 2002). The area is dominated by Orthic Gray Luvisols, which have been described as well developed, platy Ae horizons overlying Bt horizons with moderate to strong blocky mesostructure and calcareous C horizons (Howitt and Pawluk 1985). A soil survey commissioned by Alliance Pipeline Ltd. indicated that the site soil was duff over silty clay.

A second study site is located in a peatland area of the lower foothills subregion of the foothills natural region near Fox Creek, Alberta (Achuff 1994). The dominant landforms include morainal veneer over rolling bedrock, organic deposits and bedrock output (Alberta Environmental Protection 1998). Reference vegetation of the area includes *Populus tremuloides*, *Picea mariana*, *Picea glauca*, *Pinus contorta*, *Populus balsamifera* L. (balsam poplar) and *Betula papyrifera* Marsh. (white birch) forests. Reference soils are gray luvisols (Alberta Environmental Protection 1998). This site starts at KP 6.45 and ends at KP 8.1 of the Two Creeks lateral pipeline, located south of the Chickadee Creek Crossing (Figure 2.2). The 1.65 km of pipeline crosses parts of SE 7-62-15 and NW/SW/SE 6-62-15 all W5M. The site is primarily located within a mature *Picea mariana* lowland with a small upland portion dominated by *Pinus contorta* (Pockar 2002).

Both seeded and natural recovery portions of the mainline pipeline RoW had the same logging, soil handling, pipeline installation and recontouring history. The site was logged during winter 1999 and construction occurred during winter 2000. The mainline pipeline had a 32 m RoW cleared and the 914 mm pipeline was installed in a 2 m wide trench that was dug with a trenching wheel. The site runs west to east then turns and runs northwest to southeast with the RoW north of the trench making up the work side and the RoW south of the trench making up the spoil side.

The Two Creeks lateral is a former seismic line that was widened to 18 m to allow for a 1 m wide trench and installation of a 168 mm pipeline. Clearing was done in winter 1999 and construction followed in winter 2000. Final cleanup was done in winter 2001 but due to washouts and a sunken ditch, remedial work was done in January 2002. The remedial work involved a bulldozer back blading over the trench area (Hunter 2002). The site was not seeded but mature, headed out grass was observed during a field survey in spring 2002, and this grass was likely already established on the original seismic line. Direct comparison between the mainline mixedwood and lateral peatland sites cannot be made due to differences in antecedent site conditions. The site can, however, provide an opportunity to determine if the effects of natural recovery and seeding are similar on different sites.

## 3.2 Experimental Design and Treatments

Due to the linear nature of the study site, unequal lengths of revegetation treatments, and fixed pipeline RoW treatments, a split plot on a complete block design was used on the mainline mixedwood site. The study site was divided into two treatment areas, seeded and natural recovery. Three blocks were established within the seeded treatment and six blocks within the natural recovery. The number of blocks within the seeded and natural recovery treatments was based on the length of each treatment and availability of representative locations (e.g., flat terrain, no recent disturbance). Blocks were selected primarily to reduce topographic effects and secondarily, to eliminate areas of abnormal vegetation cover. Abnormal vegetation cover was defined as areas of excessively high or low cover or areas with an abnormally high proportion of invasive species. To achieve this, blocks were established in areas that were topographically neutral (mid slope) and had representative vegetation cover as defined by abundance and composition.

The seeded treatment was approximately 1 km long. Each of the three blocks was 15 m wide and extended from the shoulder of the adjacent road, across the full 32 m RoW and 5 m into the adjacent forest. Within each block there were seven pipeline RoW treatments including (width in brackets) south forest (5 m), south forest fringe (3 m), spoil where the soil material was stockpiled during construction (14 m), trench (2 m), work where the majority of vehicular traffic occurred during construction (10 m), shoulder fringe next to the road (3 m) and shoulder of the road (3 m) (Figure 2.1). As the objective was to compare natural recovery and seeding as revegetation techniques, pipeline RoW treatments were not considered in this chapter. The section was broadcast seeded in winter 2000 at a rate of 14 kg ha$^{-1}$. The seed mix was selected by Alliance Pipeline Ltd. as suitable for the area based on its previous use at similar locations. The mix included 20% *Poa palustris* L. (fowl bluegrass), 15% *Festuca ovina* L. (rocky mountain fescue), 15% *Bromus ciliatus* L. (fringed brome), 15% *Agropyron trachycaulum* (Link) Malte (slender wheatgrass), 15% *Deschampsia caespitosa* (L.)

Beauv (tufted hairgrass), 10% *Koeleria macrantha* (Ledeb.) J.A. Schultes f. (June grass), 5% *Elymus innovatus* Beal (hairy wild rye) and 5% *Oryzopsis asperifolia* Michx. (mountain rice grass).

The natural recovery treatment was approximately 2.4 km long. The entire southern 500 m was eliminated as potential study locations because of a severe erosion problem and the potential that heavy equipment was going to be brought in to stabilize and recontour the area. Natural recovery blocks were not seeded or fertilized and no erosion control strategies were employed. Each of the six blocks was 15 m wide and extended across the 32 m RoW with 5 m of forest on both sides. The pipeline RoW treatments were the same as the seeded blocks with the exception that the shoulder and shoulder fringe were replaced with second forest and forest fringe treatments (Figure 2.1).

On the lateral peatland site, there was only a natural recovery treatment, as seeding is not standard procedure on wetland areas. The site was blocked to separate topographic areas. Three blocks were established on topographic highs, which were *Pinus contorta* dominated, and three blocks were established on topographic lows, which were *Picea mariana* dominated. Each of the six blocks was 15 m wide and extended across the 18 m RoW with 5 m of forest on both sides. Within each block there were seven pipeline RoW treatments including (width in brackets) east forest (5 m), east forest fringe (2 m), work (9 m), trench (1 m), spoil (4 m), west forest fringe (2 m) and west forest (5 m) (Figure 2.2).

## 3.3 Field and Laboratory Measurements

### 3.3.1 Soil

In July 2002, soil samples were taken from the center of each RoW treatment on the main line at 10 cm increments to a depth of 30 cm using a hand auger. Seven samples per depth per block were collected. Samples were stored in Ziploc plastic bags and kept cool until they were analyzed for chemical properties. No soil samples were taken at the lateral line site as this was a secondary site for vegetation assessment only.

Organic carbon was determined using a modified Walkley-Black method (EnviroTest 2001) where soil is treated with potassium dichromate ($K_2Cr_2O_7$) and sulfuric acid

($H_2SO_4$) to oxidize organic matter (Carter 1993; EnviroTest 2001). The remaining dichromate is back titrated with ferrous ammonium sulfate [Fe $(NH_4)_2(SO_4)_2$]. Organic matter content of the samples was estimated by assuming organic matter was 58% carbon (Van Bemmelen Factor).

To determine soil electrical conductivity and pH, samples were oven dried and ground to 2 mm. Deionized water was added to thoroughly mixed soil to form a saturated paste in which measurements were taken with conductivity and pH meters (McKeague 1978; Carter 1993; EnviroTest 2001). This method has been effective for forest soils (Tremblay et al. 2002).

In addition to organic matter, electrical conductivity and pH, appropriate nutrient levels are critical for plant growth. Of particular importance are the macronutrients. This study assessed three macronutrients and their plant availability. Available nitrite-nitrate nitrogen was determined using the cadmium reduction method (Carter 1993; EnviroTest 2001). This method involves reducing nitrate to nitrite by passing the sample through a copperized cadmium column. The nitrite is then reacted with a diazotizing reagent (sulfanilimide) and a coupling reagent [N-(1-naphthyl)-ethylenediamine dihydrochloride]. The resulting solution is measured colorimetrically at 520 nm. This method is very sensitive and is not affected by organic matter and soil cations (Keeney and Nelson 1982). Available phosphate in the form orthophosphate and available potassium were determined using the modified Kelowna method (EnviroTest 2001). The extracting solution contains 0.025 M HOAc, 0.25 M $NH_4OAc$ and 0.015 M $NH_4F$ at pH 4.5. Orthophosphate reacts with the ammonium molybdate and antimony tartrate to form a complex that is then reduced with ascorbic acid and measured colorimetrically at 880 nm. To determine available potassium, the soil extract is mixed with internal standards (lithium nitrate, nitric acid and lanthanum oxide) and measured using a flame photometer (EnviroTest 2001). Light intensity is set at 768 nm.

In June 2003, further soil testing was conducted to determine bulk density, penetration resistance and particle size. An Uhland corer was used to take soil samples from the center of each RoW treatment at 10 cm increments to a depth of 30 cm. Samples were taken sequentially from the same hole. Samples were oven dried at 105 °C to constant weight. Weights were determined using an AND Scientific Balance (Model FY 3000).

Three penetration resistance measurements were taken in each RoW treatment at 0, 5, 10, 20, 30 and 40 cm using a proving ring penetrometer with a 30° circular cone with a 13 mm diameter at the base. Particle size analysis (PSA) was performed on soil samples collected at the same location as the bulk density measurements. Enviro-Test Laboratories of Edmonton, Alberta performed the analysis using the hydrometer method (Kalra and Maynard 1991).

### 3.3.2 Vegetation

A vegetation assessment was conducted on the mixedwood and peatland sites during the last week of June 2002. By assessing the vegetation at this time, both early and late species could be identified. Within each of the pipeline RoW treatments of all nine blocks, four randomly placed 0.1 $m^2$ quadrats (20 x 50 cm) were assessed for percent bare ground, litter and live cover by species. This size of quadrat was chosen because grasses and small shrubs were dominant and it has been used in similar vegetation surveys (Daubenmire 1959; Larson and Larson 1987). Cover was determined by looking down upon the canopy. A species area curve was developed to confirm that four quadrats were sufficient per treatment. A walk through survey was also performed to record the presence of species not observed in the quadrat assessments. In June 2003, when the second set of soil samples were collected, average root depths were visually assessed by washing the face of the hole left from the Uhland corer sampling.

## 3.4 Statistical Analyses

Inferential statistics were planned and the experimental design was to be treated as a split-plot as in most other pipeline research. However, due to the physical layout of the vegetation treatments, performing traditional inferential statistics such as t-tests or analysis of variance (ANOVA) was deemed not prudent (Blenis 2004). There could never be certainty that differences between seeded and natural recovery treatments were a result of the vegetation treatment and not a result of the extraneous variability caused by the physical layout. The road has the potential to serve as a vector of species transfer more rapidly than would occur without its presence.

Thus, instead of presenting p-values associated with t-tests and ANOVAs, means and confidence intervals (CIs) are presented to compare seeded and natural recovery treatments. Although the presentation of this information does not show statistical significance, it does show whether observed effects are large enough to be ecologically significant. Recently, it has been argued that presenting observed effects and their CIs is more informative that presenting p-values (Di Stefano 2003).

The data were assessed for normality using the Shapiro-Wilk test as one assumption when presenting CIs of means is that the data are normally distributed. Overall, 70% of the data were normal. The data that were not normal did not appear to follow any trend. Technically, the data that are non-normal should be presented as medians and CIs because medians are not affected by non-normality. To address this issue, medians and their CIs were calculated for all data and compared to means and their CIs. The differences between means and medians and their respective CIs do not appear to be ecologically significant. It is also assumed that if the sample size were larger, all of the data would be normal. For these reasons, the results and discussion comparing seeded and natural recovery treatments are based on data means and their CIs.

The mean and CIs presented for each of the seeded and natural recovery treatments include four of the seven pipeline RoW treatments. On the seeded treatment, the shoulder, shoulder fringe and south forest RoW treatments were removed. On the natural recovery treatment, this corresponded to the north forest, north forest fringe and the south forest RoW treatments. The objective of the analysis was to determine differences between seeded and natural recovery treatments, and leaving these areas as part of the analysis would skew the results since neither of the forest treatments was seeded. The shoulder fringe treatment on the seeded treatment was removed because it was evident that the adjacent road and transmission line RoW influenced the vegetation cover and composition. To maintain consistency between the areas being compared the north forest fringe RoW treatment on the natural recovery treatment was also removed.

# 4 Results and Discussion

## 4.1 Soils

### 4.1.1 Physical Parameters

Soil penetration resistance of seeded and natural recovery treatments differed at the surface but was similar and increased steadily with depth (Table 2.2). Penetration resistance ranged from 2.5 to 4.0 MPa at 0 and 40 cm, respectively, on the seeded treatment and from 1.8 to 4.0 MPa at the same depths under natural recovery. Although soil handling procedures were the same across the two treatments, the additional seeding activity could have compacted the seeded treatment more than the natural recovery treatment, giving the slightly higher surface values compared to the natural recovery treatment. The ranges and maximum penetration resistances correspond closely with those of Soon et al. (2000) who found that one year after pipeline installation on a gray soil of the sub humid boreal plain, highest penetration resistance was approximately 4 MPa at a 49 cm depth.

Soil bulk density followed a similar trend to that of penetration resistance (Table 2.2). On the seeded treatment, bulk density ranged from 0.9 to 1.3 Mg $m^{-3}$ and under natural recovery, it was 1.2 Mg $m^{-3}$ to 1.3 Mg $m^{-3}$ (Table 2.2). Values were within the normal range for soils of their texture class (Hausenbuiller 1985).

According to the Canadian System of Soil Classification (Soil Classification Working Group 1998) soils at all three depth intervals were clay loam textured. The clay loam texture of the upper 30 cm indicates there was some admixing during pipeline construction on both vegetation treatments. Although not always evident from particle size analyses, during soil sampling well developed Ae horizons were observed in the forest soil profiles. This indicates that clay eluviation had been occurring and a clay loam would not be expected at the surface unless clay from the subsoil was mixed. This could be a result of overstripping.

As soil compaction occurs, bulk density and penetration resistance increase contributing to decreased infiltration and hydraulic conductivity (Froehlich and McNabb 1984). Since decreased infiltration may contribute to greater runoff, and therefore increased erosion potential, reducing compaction during pipeline construction is important. This should be considered particularly important to any natural recovery project where vegetation may take a significant amount of time to develop.

Although penetration resistance can be highly variable and is influenced by soil moisture and bulk density, it is used as an indicator of the forces plant roots encounter trying to penetrate soil depths (Taylor and Gardner 1963). Values greater than 2 MPa can restrict plant root growth, although it is also recognized that root growth is strongly affected by bulk density and soil moisture (Thompson et al. 1987; Naeth et al 1991; Lowery and Schuler 1994). None of the bulk density values were sufficiently high to cause concerns for plant growth and development (Lutz 1952; Naeth et al. 1991). Impeded root development was not apparent in shallow soil pits in this study in either treatment with developed vertical roots of many species seen at depths up to 30 cm in spite of the high penetration resistance values. The discrepancy between the penetration resistance measurements and the bulk density measurements could be related to the low precipitation received that year.

### 4.1.2 Chemical Parameters

The soil chemical parameters measured were consistent between seeded and natural recovery treatments and no values were considered atypical for a gray wooded soil (Table 2.3). Electrical conductivities ranged from 0.17 to 0.21 dS $m^{-1}$, pH ranged from 7.2 to 7.5, and organic matter from 2.1 to 4.4%, decreasing with depth. All macronutrients were normal for forest soils and decreased with depth with the exception of nitrate levels in the seeded treatment, which remained constant with depth.

As expected in an area that receives approximately 580 mm of precipitation annually, electrical conductivities were low. Values were slightly lower than those from a study by Soon et al. (2000) in the boreal plains of Alberta. Mean pH had a very narrow range of 7.2 to 7.5 across the two treatments. Although not high, pH was slightly above the ideal ranges for some *Trifolium* species, *Vicia americana* Muhl. (American vetch) and many grasses (Havelin et al. 1999). Despite this, these species established and in general appeared healthy and vigorously growing.

Organic matter was slightly higher on the seeded treatment than on the natural recovery treatment at 0 to 10 cm depth, but was slightly lower at 10 to 30 cm depths. As expected, organic matter decreased with depth on both treatments indicating salvaged organic material was primarily replaced on the surface. By maintaining organic matter in the upper soil profile, favorable conditions for plant growth were maintained. It also important from the standpoint of maintaining a viable seed bank for natural recovery. Organic matter at 0 to 10 cm was comparable to that of logged, but not stripped, mixedwood forest soils studied in central Alberta (McNabb et al. 2001).

Of all the soil chemical parameters assessed, organic matter content may be the most important because of its broad influence on other soil characteristics (Havelin et al. 1999). Organic matter directly or indirectly affects mineralization, nutrient retention, water retention, cation exchange, chelating ability of soil and buffering capacity (Havelin et al. 1999). Furthermore, most soil quality problems are related to low organic matter levels (Robertson 1979). Soil electrical conductivity and pH can also significantly impact plant community establishment and success (Havelin et al. 1999). Soils with an electrical conductivity greater than 4 dS $m^{-1}$ are typically considered unsuitable for plant growth as they restrict water uptake (Koenig 1997; Havelin 1999). Soil pH is important when studying vegetation establishment because pH can strongly influence nutrient availability (Ste-Marie and Pare 1999).

## 4.2 Vegetation

### 4.2.1 Mixedwood Forest

A total of 52 herbaceous and 11 woody species were identified. Of the herbaceous species, 21 were common to both seeded and natural recovery treatments (Table 2.4). Of the native woody species, one was common to both seeded and natural recovery treatments; six were found only on the natural recovery treatment and four were found only on the seeded treatment (Tables 2.5 and 2.6). Of the native herbaceous species, 15 were common, nine were found only on seeded treatments and 17 were found only under natural recovery (Tables 2.5 and 2.6). Of the introduced herbaceous species, six were common, four were found only on seeded treatments and one was only found under natural recovery. Thus the natural recovery treatment more closely approximated the desired native plant community with 23 native species that were not found on the seeded treatment. Weedy species were not a management issue on either treatment (Tables 2.4 to 2.6). Although *Sonchus arvensis* and *Taraxacum officinale* were present on both treatments, they accounted for only a small portion of the overall cover.

Species richness (63 plant species) on this site was higher than that (54) found by Ealey and Virgl (2002) in the boreal forest of west-central Saskatchewan. While this study found seven more species on the natural recovery than the seeded treatment, Ealey and Virgl (2002) found 41 more species. Despite common climatic and soil conditions between sites, seeding on the Saskatchewan site restricted growth of native species more than on this research site due to the species that were seeded and the rate that was used. The species seeded were 41.7% *Festuca rubra* L. (creeping red fescue) (12.72 kg ha$^{-1}$), 20.8% *Phleum pratense L.* (timothy) (6.34 kg ha$^{-1}$), 9.2% *Agropyron trachycaulum* (2.80 kg ha$^{-1}$), 7.5% *Agropyron dasystachyum* (Hook.) Scribner. (northern wheatgrass) (2.29 kg ha$^{-1}$) and 20.8% *Trifolium repens* L. (white clover) (6.34 kg ha$^{-1}$). Of these species, only *Agropyron trachycaulum* is common between the Saskatchewan study and the current study. The aggressive nature and high percentages of all the seeded species would have limited other species growth and development. Seeding rate was 30.5 kg ha$^{-1}$, which was more than double the rate used on this study site.

The five species with the highest live canopy cover on the seeded treatment were *Trifolium pratense* L. (red clover), *Agropyron trachycaulum*, *Vicia americana*, *Trifolium repens* and *Trifolium hybridium* L. (alsike clover) (Tables 2.4 and 2.5) Two species in the seed mix (*Oryzopsis asperifolia and Bromus ciliatus*) were not found, while four species (*Elymus innovatus, Poa palustris, Koeleria macrantha and Deschampsia caespitosa*) were present with less than 0.4% cover each. *Agropyron trachycaulum* was the second most dominant species on this treatment with 8.83% live cover and was not found on the natural recovery treatment. It was the only seeded grass to account for more than 1% vegetation cover. The five dominant species on the natural recovery treatment were *Trifolium pratense*, *Trifolium hybridum*, *Vicia americana*, *Lathyrus ochroleucus* Hook and *Elymus innovatus* (Tables 2.4 and 2.6). *Rubus pubescens* Raf, (dewberry) a native shrub, was the most dominant species found only on the natural recovery treatment with a mean live cover of < 1%.

Despite being part of the seed mix, *Vicia americana* and *Elymus innovatus* had more than twice as much cover on the natural recovery treatment than on the seeded treatment. This is an indication that they are being out competed by other seeded species such as *Agropyron trachycaulum*, as this latter species was not found in natural recovery treatments. Removing *Vicia americana* and *Elymus innovatus* from the seed mix is warranted as they can successfully establish from the seed bank if highly competitive species are not seeded. Of the four seeded species that established on the seeded treatment, only *Poa palustris* (0.2% cover) was found on the natural recovery treatment.

The natural recovery and seeded treatments had similar live cover of 43.2 and 41.9%, respectively (Table 2.7). Bare ground (44.2%) was higher on the natural recovery treatment compared to the seeded treatment (32.8%). This was due to increased litter (24.5%) with seeding compared to natural recovery (12.6%). The seeded treatment likely had greater plant establishment and growth during the first season (2001) that resulted in greater litter, which was measured in the second growing season (2002). This was expected considering vegetation establishment under natural recovery results from the seed bank and invasion. Previous research has shown that after disturbances germination of seed bank species may occur over many years (Granström 1986). In 2003 little bare ground was observed on either of the treatments. Regardless of the differences between the two revegetation treatments, neither would have met the requirement of 50% vegetation cover set out in the 2001 Pipeline Reclamation Criteria (Alberta Environment 2001), although litter cover was adequate.

Vegetation cover was good on both revegetation treatments, considering the assessment was done during the second growing season. On a seeded 20 m wide pipeline RoW in southern Alberta mixed grass prairie, live cover did not exceed 10% after two growing seasons (Petherbridge 2000) likely influenced by less than 300 mm of annual precipitation. After 10 years in another study on a seeded 18 m wide RoW in southern Alberta, live cover was less than 15% (Ostermann 2001). However, that site had 73 and 77% litter cover and received approximately 340 mm of annual precipitation. If high live cover is continued to be used as a measure of reclamation success, natural recovery may be a reclamation tool that is limited for use in areas where precipitation is not limiting.

Although rainfall in 2001 and 2002 was lower than the long term average, key precipitation events helped the vegetation establish. In the first growing season (2001) the annual precipitation was low but in June and July there was over 316 mm of rainfall. In 2002, the annual precipitation was low again but there was a large amount of snowfall (107.6 cm) in March and April that would have provided early spring moisture. These key events undoubtedly contributed to the high cover measured during the 2002 field season.

On the basis of vegetation cover, both natural recovery and seeding on the mixedwood site were successful. However, when species composition of the two vegetation treatments is evaluated, both treatments were dominated by non-seeded, non-native forbs. All three of the dominant *Trifolium* spp. were introduced legumes. Whether these species were introduced by construction equipment or migrated via seed rain from nearby disturbed sites, they are dominating both treatments. They are, however, nitrogen fixing legumes and can enhance soil nitrogen, which is typically low in forest soils. *Vicia americana* is also a legume, although native, and was part of the seed mix applied to the seeded treatment.

### 4.2.2 Peatland

A total of 32 herbaceous and 14 woody species were identified. Of the herbaceous species, 14 were common to both the topographic high and low treatments (Table 2.8). Five native herbaceous species were found only on the topographic high treatment and 11 were found only on the topographic low treatment (Tables 2.9 and 2.10). Of the native woody species identified, four were common to both topographic high and low treatments. Seven woody species were found only on the topographic high treatment and three species were found only on the topographic low treatment. The topographic high treatment had one introduced forb and one introduced grass, while the low treatment had no introduced species (Tables 2.8 to 2.10).

The topographic high and low treatments had mean live cover of 15.5 and 44.2%, respectively (Table 2.11). Bare ground was much higher on the high treatment at 68.6% compared to 36.0% on the low treatment. The difference in bare ground between the two treatments was directly related to live canopy cover, as litter cover differed by less than 4%.

The five species with the highest canopy cover on the topographic high treatment were *Epilobium angustifolium* L (fireweed), *Vaccinium myrtilloides* Michx. (blueberry), *Carex* species (sedges), *Equisetum sylvaticum* L. (woodland horsetail) and *Salix lutea* Nutt. (yellow willow) (Tables 2.8 and 2.9). Despite being dominant species, combined they produced less than 8% of the vegetation cover. The species with the highest cover on the topographic low treatment were *Calamagrostis canadensis* Michx. (marsh reed grass) *Carex aquatilus* Wahlenb. (water sedge), *Carex* species, *Agrostis scabra* and *Glyceria striata* (Lam.) A.S. Hitchc. (fowl manna grass) (Tables 2.8 and 2.10). The only dominant species that were classified as common in both topographic highs and lows were *Carex* species. As they were not identified to species, all that can be concluded is that both topographic positions had appreciable amounts of *Carex.*

Vegetation, bare ground and litter cover on the mixedwood treatments were comparable to cover observed in the topographic low treatment of the peatland site. However, the topographic high positions in the peatland had very little vegetation cover and high amounts of bare ground. This suggests that seeding these topographic high positions within peatlands may be potentially beneficial. Considering that the high and low treatments were often separated by less than 100 m, it is apparent that moisture levels are influencing vegetation establishment. Not only is moisture influencing ground cover, but it also influences species composition.

## 5. Summary and Conclusions

- After two growing seasons, natural recovery of this section of the Alliance Pipeline Ltd. RoW in the boreal forest resulted in a numerically higher vegetation cover than that of an adjacent seeded area; from an ecological perspective, cover was not different.
- The vegetation community that developed on the natural recovery treatment had greater species richness and fewer invasive species than the seeded treatment; it was more desirable ecologically than the community on the seeded treatment.

- Introduced *Trifolium* species dominated both seeded and natural recovery treatments.
- Two of the six seeded species, *Bromus ciliatus* and *Oryzopsis hymenoides*, failed to establish.
- The ground cover characteristics of the topographic lows on the lateral line RoW more closely resembled those of the mixedwood sites on the mainline pipeline than did the cover on the topographic highs.
- Soil properties did not differ significantly between seeded and natural recovery treatments.

In conclusion, the natural recovery treatment resulted in similar soil physical and chemical properties and vegetation cover, greater species richness and fewer introduced species than the seeded treatment. This provides strong support for its use as a revegetation method on pipeline RoW in the boreal forest to maintain landscape structure, function and ecological integrity. Topographic highs surrounded by peatland may be good candidates for seeding.

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Table 2.1. Climate data for the Environment Canada weather station near Whitecourt, Alberta.

| | 1971-2001 | 2001 | 2002 | 2003 |
|---|---|---|---|---|
| Summer (April to September) | | | | |
| Daily Mean Temperature (°C) | 11.8 | 12.0 | 12.6 | 11.6 |
| Minimum Typical Temperature (°C) | 5.0 | 5.8 | 4.1 | 5.5 |
| Maximum Typical Temperature (°C) | 17.5 | 18.2 | 12.6 | 17.6 |
| Winter (October to March) | | | | |
| Daily Mean (°C) | -6.0 | -9.2 | -5.3 | -5.8 |
| Minimum Typical Temperature | -11.1 | -9.2 | -9.9 | -10.7 |
| Maximum Typical Temperature | -0.9 | 0.6 | -0.8 | -0.9 |
| Annual Mean (°C) | 2.6 | 3.9 | 2.5 | 2.9 |
| Annual Rainfall (mm) | 440.3 | 393.9 | 204.8 | 208.7 |
| Annual Snowfall (cm) | 178.1 | 105.0 | 198.0 | 253.4 |
| Total Annual Precipitation (mm) | 577.7 | 471.4 | 365.3 | 407.0 |

The weather station is located at 54° 8' N, 115° 47' W, 782.40 masl (Environment Canada 2004).

Table 2.2. Soil physical parameters on the seeded and natural recovery treatments in the mixedwood site in 2003.

| | Seeded | | | Natural Recovery | | |
|---|---|---|---|---|---|---|
| Parameter | Mean | UCL | LCL | Mean | UCL | LCL |
| Penetration Resistance (MPa) | | | | | | |
| Surface | 2.5 | 3.3 | 1.8 | 1.8 | 2.2 | 1.5 |
| 2 cm | 2.8 | 3.5 | 2.1 | 2.8 | 3.4 | 2.3 |
| 4 cm | 3.4 | 4.1 | 2.6 | 3.2 | 3.8 | 2.7 |
| 8 cm | 3.6 | 4.4 | 2.9 | 3.6 | 4.2 | 3.0 |
| 12 cm | 3.8 | 4.5 | 3.1 | 3.8 | 4.4 | 3.2 |
| 16 cm | 4.0 | 4.7 | 3.3 | 4.0 | 4.5 | 3.3 |
| Bulk Density (Mg m$^{-3}$) | | | | | | |
| 0-10 cm | 0.9 | 1.1 | 0.8 | 1.2 | 1.3 | 1.0 |
| 10-20 cm | 1.2 | 1.3 | 1.0 | 1.3 | 1.4 | 1.1 |
| 20-30 cm | 1.3 | 1.4 | 1.2 | 1.3 | 1.4 | 1.2 |
| % Sand | | | | | | |
| 0-10 cm | 33.7 | 36.6 | 30.8 | 33.3 | 37.3 | 29.4 |
| 10-20 cm | 34.4 | 42.7 | 26.2 | 27.6 | 34.0 | 21.1 |
| 20-30 cm | 32.0 | 40.2 | 23.8 | 24.1 | 32.5 | 15.6 |
| % Silt | | | | | | |
| 0-10 cm | 29.6 | 34.1 | 24.8 | 30.4 | 34.9 | 26.6 |
| 10-20 cm | 27.8 | 32.8 | 22.7 | 33.2 | 38.4 | 27.9 |
| 20-30 cm | 27.7 | 32.2 | 23.2 | 28.1 | 32.5 | 23.7 |
| % Clay | | | | | | |
| 0-10 cm | 36.7 | 38.4 | 34.9 | 36.3 | 41.7 | 30.8 |
| 10-20 cm | 38.0 | 45.4 | 30.6 | 39.3 | 46.4 | 32.3 |
| 20-30 cm | 40.4 | 48.2 | 32.7 | 47.9 | 58.5 | 37.3 |

N = 12 for all parameters
UCL = Upper confidence limit at 95%, LCL = Lower confidence limit at 95%

Table 2.3. Soil chemical parameters on the seeded and natural recovery treatments in the mixedwood site in 2002.

| | Seeded | | | Natural Recovery | | |
|---|---|---|---|---|---|---|
| Parameter | Mean | UCL | LCL | Mean | UCL | LCL |
| Electrical Conductivity (dS $m^{-1}$) | | | | | | |
| 0-10 cm | 0.21 | 0.27 | 0.15 | 0.19 | 0.21 | 0.17 |
| 10-20 cm | 0.20 | 0.23 | 0.17 | 0.18 | 0.22 | 0.15 |
| 20-30 cm | 0.17 | 0.21 | 0.13 | 0.19 | 0.23 | 0.16 |
| Soil pH | | | | | | |
| 0-10 cm | 7.5 | 7.8 | 7.2 | 7.4 | 7.6 | 7.1 |
| 10-20 cm | 7.4 | 7.7 | 7.1 | 7.2 | 7.5 | 7.0 |
| 20-30 cm | 7.4 | 7.8 | 7.0 | 7.2 | 7.5 | 6.8 |
| Organic Carbon (%) | | | | | | |
| 0-10 cm | 2.5 | 3.2 | 1.9 | 2.3 | 2.8 | 1.9 |
| 10-20 cm | 1.5 | 1.9 | 1.2 | 1.8 | 2.2 | 1.4 |
| 20-30 cm | 1.3 | 1.6 | 0.9 | 1.5 | 1.9 | 1.1 |
| Organic Matter (%) | | | | | | |
| 0-10 cm | 4.4 | 5.5 | 3.2 | 4.0 | 4.8 | 3.2 |
| 10-20 cm | 2.6 | 3.3 | 2.0 | 3.1 | 3.7 | 2.4 |
| 20-30 cm | 2.1 | 2.7 | 1.6 | 2.6 | 3.2 | 1.9 |
| Nitrate (mg $kg^{-1}$) | | | | | | |
| 0-10 cm | 2.6 | 2.8 | 2.7 | 2.5 | 2.8 | 2.2 |
| 10-20 cm | 2.6 | 2.7 | 2.4 | 2.0 | 2.3 | 1.8 |
| 20-30 cm | 2.7 | 3.3 | 2.2 | 2.0 | 2.2 | 1.8 |

Table 2.3. Soil chemical parameters on the seeded and natural recovery treatments in the mixedwood site in 2003 (continued)

| | Seeded | | | Natural Recovery | | |
|---|---|---|---|---|---|---|
| Parameter | Mean | UCL | LCL | Mean | UCL | LCL |
| Phosphate (mg $kg^{-1}$) | | | | | | |
| 0-10 cm | 11 | 16 | 7 | 14 | 20 | 8 |
| 10-20 cm | 6 | 8 | 3 | 8 | 11 | 5 |
| 20-30 cm | 3 | 4 | 2 | 5 | 6 | 3 |
| Potassium (mg $kg^{-1}$) | | | | | | |
| 0-10 cm | 179 | 201 | 157 | 184 | 199 | 169 |
| 10-20 cm | 158 | 191 | 125 | 180 | 197 | 164 |
| 20-30 cm | 166 | 201 | 132 | 173 | 190 | 157 |

N = 12 for seeded, N = 24 for natural recovery parameters

UCL = Upper confidence limit at 95%, LCL = Lower confidence limit at 95%

Table 2.4. Mean cover and standard deviation of species common to seeded and natural recovery treatments in the mixedwood site in 2002.

| | | Seeded | | Natural Recovery | |
|---|---|---|---|---|---|
| Scientific Name | Common Name | Cover (%) | SD | Cover (%) | SD |
| Native Shrubs and Trees | | | | | |
| *Rosa acicularis* Lindl | Prickly Rose | 1.52 | 2.08 | 0.13 | 0.17 |
| Native Forbs | | | | | |
| *Aralia nudicaulis* L. | Wild Sarsaparilla | 0.42 | 0.83 | 0.31 | 0.63 |
| *Cornus canadensis* L. | Bunchberry | 1.40 | 2.79 | 0.16 | 0.31 |
| *Fragaria virginiana* Duchesne | Wild Strawberry | 0.27 | 0.54 | 0.86 | 0.91 |
| *Galeopsis* species L. | Nettle | 0.02 | 0.04 | 0.02 | 0.04 |
| *Lathyrus* species L. | Peavine | 1.42 | 2.03 | 0.14 | 0.20 |
| *Lathyrus ochroleucus* Hook | Cream Colored Peavine | 1.21 | 1.28 | 4.40 | 1.70 |
| *Mertensia paniculata* (Ait) G. Don | Tall Bluebells | 0.31 | 0.63 | 0.43 | 0.50 |
| *Vicia americana* Muhl | Wild Vetch | 3.95 | 1.97 | 8.40 | 4.35 |
| Native Grasses, Sedges and Horsetails | | | | | |
| *Agrostis scabra Willd* | Tickle Grass | 0.30 | 0.37 | 0.09 | 0.17 |
| *Calamagrostis canadensis* Michx | Bluejoint/Marsh Reed Grass | 0.58 | 1.17 | 0.27 | 0.46 |
| *Carex* species L. | Sedge | 0.01 | 0.02 | 0.04 | 0.06 |
| *Elymus innovatus* Beal | Hairy Wild Rye | 0.04 | 0.08 | 0.79 | 1.58 |
| *Equisetum arvense* L. | Common Horsetail | 0.52 | 0.52 | 0.05 | 0.04 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | 0.04 | 0.08 | 0.02 | 0.04 |
| *Poa palustris* L. | Fowl Bluegrass | 0.38 | 0.51 | 0.18 | 0.35 |

Table 2.4. Mean cover and standard deviation of species common to both the seeded and natural recovery treatments in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Seeded Cover (%) | Seeded SD | Natural Recovery Cover (%) | Natural Recovery SD |
|---|---|---|---|---|---|
| Introduced Forbs | | | | | |
| *Melilotus* species L. | Sweet Clover | 0.03 | 0.04 | 0.61 | 1.23 |
| *Sonchus arvensis* L. | Perennial Sow Thistle | 0.21 | 0.42 | 0.31 | 0.50 |
| *Taraxacum officinale* Weber | Dandelion | 0.56 | 0.76 | 0.68 | 0.39 |
| *Trifolium hybridium* L. | Alsike Clover | 2.85 | 5.05 | 9.83 | 7.88 |
| *Trifolium pratense* L. | Red Clover | 11.54 | 4.60 | 13.89 | 6.65 |
| *Trifolium repens* L. | White Clover | 2.92 | 4.79 | 0.04 | 0.08 |
| | | | | | |
| Introduced Grasses, Sedges and Horsetails | | | | | |
| None | | | | | |

N = 60 for seeded, N = 120 for natural recovery

SD = standard deviation

Table 2.5. Mean cover and standard deviation of species found only on the seeded treatment in the mixedwood site in 2002.

| Scientific Name | Common Name | Cover (%) | SD |
|---|---|---|---|
| Native Shrubs and Trees | | | |
| *Sheperdia canadensis* (L.) Nutt | Canada Buffaloberry | 0.31 | 0.63 |
| *Linnaea borealis* L. | Twin Flower | 0.13 | 0.25 |
| *Ribes* species L. | Unknown Currant | 0.04 | 0.08 |
| *Vaccinium vitis-idea* L. | Bog Cranberry | 0.04 | 0.08 |
| Native Forbs | | | |
| *Epilobium angustifolium* L. | Fireweed | 0.31 | 0.36 |
| *Fragaria vesca* L. | Woodland Strawberry | 0.27 | 0.54 |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | 0.21 | 0.42 |
| Native Grasses, Sedges and Horsetails | | | |
| *Agropyron trachycaulum* (Link) Malte | Slender Wheatgrass | 8.83 | 3.24 |
| *Schizachne purpurascens* Swallen | Purple Oatgrass | 1.30 | 1.09 |
| *Festuca* species L. | Fescue | 1.18 | 2.03 |
| *Koeleria macrantha* (Ledeb) J.A. Schultes | Junegrass | 0.25 | 0.22 |
| *Deschampsia caespitosa* (L.) Beauv | Tufted Hairgrass | 0.11 | 0.20 |
| *Festuca saximontana* Rydb | Rocky Mountain Fescue | 0.02 | 0.04 |
| Introduced Grasses, Sedges and Horsetails | | | |
| *Festuca ovina* L. | Sheep Fescue | 0.69 | 0.70 |

Table 2.5. Mean cover and standard deviation of species found only on the seeded treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Cover (%) | SD |
|---|---|---|---|
| Introduced Forbs | | | |
| *Melilotus officinalis* (L.) Lam | Yellow Sweet Clover | 3.46 | 4.27 |
| *Trifolium* species L. | Clover | 0.02 | 0.04 |
| *Melilotus alba* Desr | White Sweet Clover | 0.01 | 0.02 |

N = 60

SD = standard deviation

Table 2.6. Mean cover and standard deviation of species found only on the natural recovery treatment in the mixedwood site in 2002.

| Scientific Name | Common Name | Cover (%) | SD |
|---|---|---|---|
| Native Shrubs and Trees | | | |
| *Rubus idaeus* L. | Wild Red Raspberry | 0.24 | 0.40 |
| *Salix* species L. | Willow | 0.24 | 0.40 |
| *Populus balsamifera* L. | Balsam Poplar | 0.15 | 0.24 |
| *Betula papyrifera* (Marsh.) | White Birch | 0.13 | 0.25 |
| *Populus tremuloides* Michx | Trembling Aspen | 0.03 | 0.06 |
| *Lonicera involucrata* (Richards) Banks | Bracted Honeysuckle | 0.01 | 0.01 |
| Native Forbs | | | |
| *Rubus pubescens* Raf | Dewberry | 0.83 | 1.40 |
| *Plantago major* L. | Common Plantain | 0.44 | 0.46 |
| *Potentilla arguta* Pursh | White Cinquefoil | 0.20 | 0.17 |
| *Galeopsis tetrahit* L. | Hemp Nettle | 0.16 | 0.31 |
| *Aster* species L. | Aster | 0.15 | 0.29 |
| *Geranium bicknellii* Britt | Bicknell's Geranium | 0.11 | 0.16 |
| *Aster ciliolatus* Lindl | Lindley's Aster | 0.10 | 0.21 |
| *Achillea millefolium* L. | Common Yarrow | 0.07 | 0.15 |
| *Viola* species L. | Violet | 0.07 | 0.10 |
| *Aster puniceus* L. | Purple Stemmed Aster | 0.05 | 0.04 |
| Unknown Forb | Unknown Forb | 0.05 | 0.10 |
| *Aster hesperius* A. Gray | Western Willow Aster | 0.02 | 0.04 |
| *Aster laevis* L. | Smooth Aster | 0.01 | 0.02 |
| *Pyrola* species L. | Wintergreen | 0.01 | 0.01 |

Table 2.6. Mean cover and standard deviation of species found only on the natural recovery treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Cover (%) | SD |
|---|---|---|---|
| Native Grasses, Sedges and Horsetails | | | |
| *Equisetum pratense* Ehrh | Meadow Horsetail | 0.16 | 0.07 |
| *Carex crawfordii* Fern | Crawford's Sedge | 0.07 | 0.09 |
| *Carex aurea* Nutt | Golden Sedge | 0.04 | 0.06 |
| Introduced Grasses, Sedges and Horsetails | | | |
| *Phleum pratense* L. | Timothy | 0.35 | 0.14 |
| Introduced Forbs | | | |
| None | | | |

N = 120

SD = standard deviation

Table 2.7. Summary of ground cover characteristics on the seeded and natural recovery treatments in the mixedwood site in 2002.

| | Seeded | | | Natural Recovery | | |
|---|---|---|---|---|---|---|
| Characteristic | Mean | UCL | LCL | Mean | UCL | LCL |
| Live Vegetation (%) | 41.9 | 52.0 | 31.8 | 43.2 | 53.4 | 32.9 |
| Bare Ground (%) | 32.8 | 47.7 | 17.9 | 44.2 | 54.9 | 33.5 |
| Litter (%) | 24.5 | 33.9 | 15.1 | 12.6 | 18.0 | 7.3 |

N = 12 for seeded, N = 24 for natural recovery parameters

Table 2.8. Mean cover of plant species common to both the topographic low and high treatments in the peatland site in 2002.

| | | Topographic High | | Topographic Low | |
|---|---|---|---|---|---|
| Scientific Name | Common Name | Cover (%) | SD | Cover (%) | SD |
| Mosses | Unknown Mosses | 2.80 | 7.58 | 22.63 | 29.25 |
| | | | | | |
| Native Shrubs and Trees | | | | | |
| *Betula glandulosa* Michx | Bog Birch | 0.02 | 0.13 | 0.36 | 1.29 |
| *Ledum groenlandicum* Oeder | Common Labrador Tea | 0.43 | 1.87 | 0.80 | 3.76 |
| *Salix lutea* Nutt. | Yellow Willow | 0.73 | 5.18 | 1.32 | 6.35 |
| *Vaccinium vitis-idaea* L. | Bog Cranberry | 0.02 | 0.13 | 0.09 | 0.67 |
| | | | | | |
| Native Forbs | | | | | |
| *Cornus canadensis L.* | Bunchberry | 0.72 | 1.64 | 0.09 | 0.67 |
| *Epilobium angustifolium* L. | Fireweed | 2.68 | 7.13 | 0.38 | 2.07 |
| *Epilobium palustre* L. | Marsh Willow Herb | 0.02 | 0.13 | 0.32 | 1.16 |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | 0.58 | 2.11 | 0.18 | 1.10 |
| *Rubus chamaemorus* L. | Cloudberry | 0.27 | 1.10 | 1.02 | 3.13 |
| *Rubus pubescens* Raf | Dewberry | 0.08 | 0.65 | 0.41 | 1.64 |
| | | | | | |
| Native Grasses, Sedges and Horsetails | | | | | |
| *Agrostis scabra* Willd | Tickle Grass | 0.15 | 0.55 | 2.68 | 5.27 |
| *Calamagrostis canadensis* Michx | Bluejoint/Marsh Reed Grass | 0.60 | 1.76 | 6.54 | 14.39 |
| *Carex crawfordii* Fern. | Crawford's Sedge | 0.47 | 2.46 | 0.13 | 0.57 |
| *Carex* species L. | Sedge | 1.15 | 3.64 | 4.05 | 7.45 |
| *Equisetum arvense* L. | Common Horsetail | 0.55 | 2.35 | 0.64 | 1.82 |

Table 2.8. Mean cover of plant species common to both the topographic low and high treatments in the peatland site in 2002 (continued).

| Scientific Name | Common Name | Seeded<br>Cover (%) | Seeded<br>SD | Natural Recovery<br>Cover (%) | Natural Recovery<br>SD |
|---|---|---|---|---|---|
| *Equisetum scirpoides* Michx | Dwarf Scouring Rush | 0.12 | 0.56 | 0.64 | 4.05 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | 0.77 | 2.40 | 0.84 | 4.08 |
| Introduced Grasses, Sedges and Horsetails | | | | | |
| *Festuca* species L. | Fescue | 0.27 | 1.23 | 0.07 | 0.42 |
| Introduced Forbs | | | | | |
| None | | | | | |

N = 84
SD = standard deviation

Table 2.9. Mean live cover of plant species found only on the topographic high treatment in the peatland site in 2002.

| Scientific Name | Common Name | Cover (%) | SD |
|---|---|---|---|
| Native Shrubs and Trees | | | |
| *Vaccinium myrtilloides* Michx | Blueberry | 2.65 | 8.72 |
| *Betula pumila* L. | Dwarf Birch | 0.25 | 1.94 |
| *Salix maccalliana* Rowlee | Maccall's Willow | 0.08 | 0.65 |
| *Gaultheria hispidula* (L.) Bigel. | Creeping Snowberry | 0.03 | 0.26 |
| *Rosa acicularis* Lindl | Prickly Rose | 0.10 | 0.66 |
| *Linnaea borealis* L. | Twin-flower | 0.02 | 0.13 |
| *Vaccinium caespitosum* Michx. | Dwarf Bilberry | 0.02 | 0.13 |
| Native Forbs | | | |
| *Mertensia paniculata* (Ait) G. Don | Tall Bluebells | 0.10 | 0.66 |
| *Achillea millefolium* L. | Common Yarrow | 0.05 | 0.39 |
| *Galeopsis tetrahit* L. | Hemp Nettle | 0.03 | 0.26 |
| Native Grasses, Sedges and Horsetails | | | |
| *Elymus innovatus* Beal | Hairy Wild Rye | 0.22 | 1.32 |
| *Calamagrostis inexpansa* A. Gray | Northern Reed Grass | 0.02 | 0.13 |
| Introduced Grasses, Sedges and Horsetails | | | |
| *Festuca ovina* L. | Sheep Fescue | 0.02 | 0.13 |

Table 2.9. Mean cover of plant species found only on the topographic high treatment in the peatland site in 2002 (continued).

| Scientific Name | Common Name | Cover (%) | SD |
|---|---|---|---|
| Introduced Forbs | | | |
| *Trifolium repens* L. | White Clover | 0.17 | 1.29 |

N = 60
SD = standard deviation

Table 2.10. Mean cover of plant species found only on the topographic low treatment in the peatland site in 2002.

| Scientific Name | Common Name | Cover (%) | SD |
|---|---|---|---|
| Native Shrubs and Trees | | | |
| *Salix pedicellaris* Pursh | Bog Willow | 0.48 | 2.02 |
| *Rubus idaeus* L. | Wild Red Raspberry | 0.09 | 0.67 |
| *Salix petiolaris* J.E. Smith | Basket Willow | 0.02 | 0.13 |
| Native Forbs | | | |
| *Andromeda polifolia* L. | Bog Rosemary | 0.02 | 0.13 |
| *Calla palustris* L. | Water Arum | 0.80 | 6.01 |
| *Kalmia polifolia* Wang. | Northern Bog Laurel | 0.04 | 0.19 |
| *Potentilla norvegica* L. | Rough Cinqefoil | 1.00 | 3.04 |
| *Smilacina stellata (L.) Desf.* | Star Flowered Solomon's Seal | 0.66 | 2.35 |
| *Aster pansus* Blake | Tufted White Aster | 0.27 | 2.00 |
| Native Grasses, Sedges, Ferns and Horsetails | | | |
| *Carex aquatilus* Wahlenb. | Water Sedge | 4.30 | 6.81 |
| *Glyceria striata* (Lam.) A.S. Hitchc. | Fowl Manna Grass | 2.00 | 8.07 |
| *Equisetum hyemale* L. | Common Scouring Rush | 1.68 | 2.28 |
| *Eriophorum angustifolium* Honck. | Tall Cotton Grass | 0.05 | 0.40 |
| Unknown Fern | Unknown Fern | 0.02 | 0.13 |
| Introduced Species | | | |
| None | | | |

N = 60

SD = standard deviation

Table 2.11. Summary of ground cover characteristics on the topographic low and high treatments in the peatland site in 2002.

| | Topographic High | | Topographic Low | |
|---|---|---|---|---|
| Characteristic | Mean | SD | Mean | SD |
| Live Cover (%) | 15.48 | 15.89 | 44.18 | 31.24 |
| Bare Ground (%) | 68.63 | 20.98 | 36.04 | 31.06 |
| Litter (%) | 16.05 | 12.03 | 19.52 | 18.01 |

N = 60
SD = standard deviation

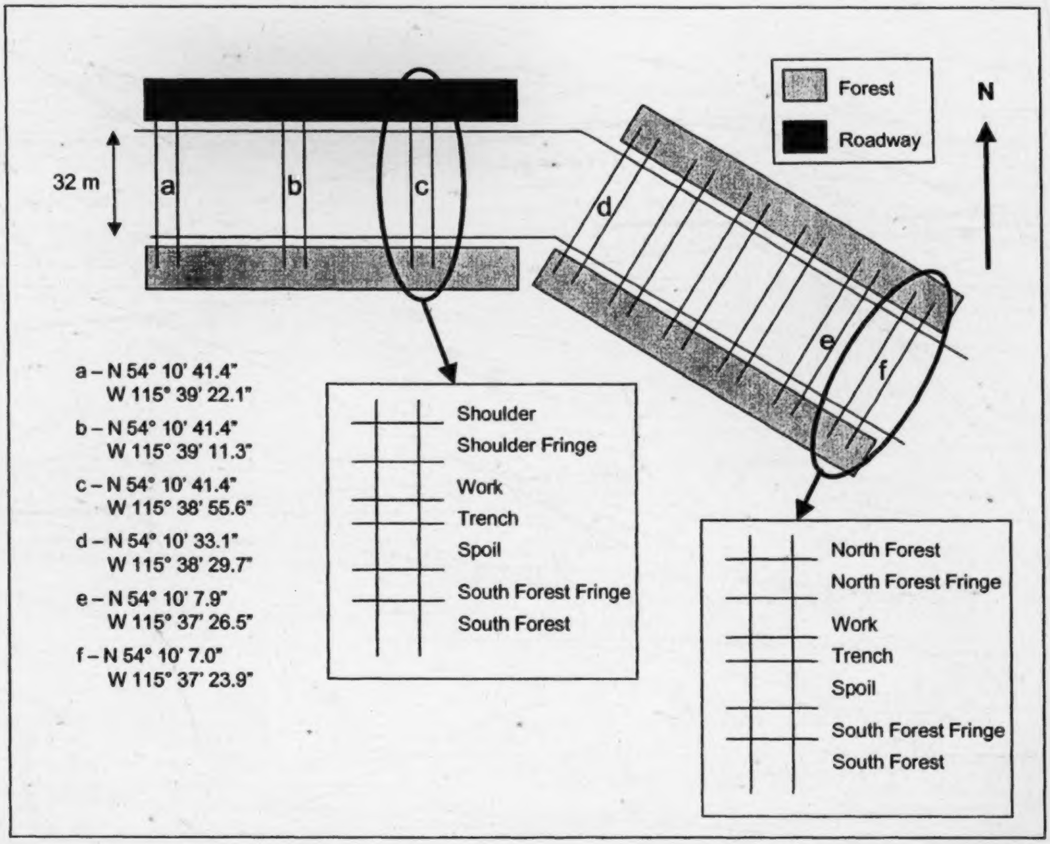
Forest
Roadway
N
32 m
a
b
c
d
e
f
a – N 54° 10' 41.4"
W 115° 39' 22.1"
b – N 54° 10' 41.4"
W 115° 39' 11.3"
c – N 54° 10' 41.4"
W 115° 38' 55.6"
d – N 54° 10' 33.1"
W 115° 38' 29.7"
e – N 54° 10' 7.9"
W 115° 37' 26.5"
f – N 54° 10' 7.0"
W 115° 37' 23.9"
Shoulder
Shoulder Fringe
Work
Trench
Spoil
South Forest Fringe
South Forest
North Forest
North Forest Fringe
Work
Trench
Spoil
South Forest Fringe
South Forest

Figure 2.1. Schematic of mainline pipeline mixedwood forest site. The three blocks adjacent to the roadway are in the seeded treatment and the six blocks with forest on both sides are in the natural recovery treatment. The enlarged blocks show the pipeline installation treatments within the seeded and natural recovery treatments. The letters (a-f) correspond to the center of the trench location within each block.

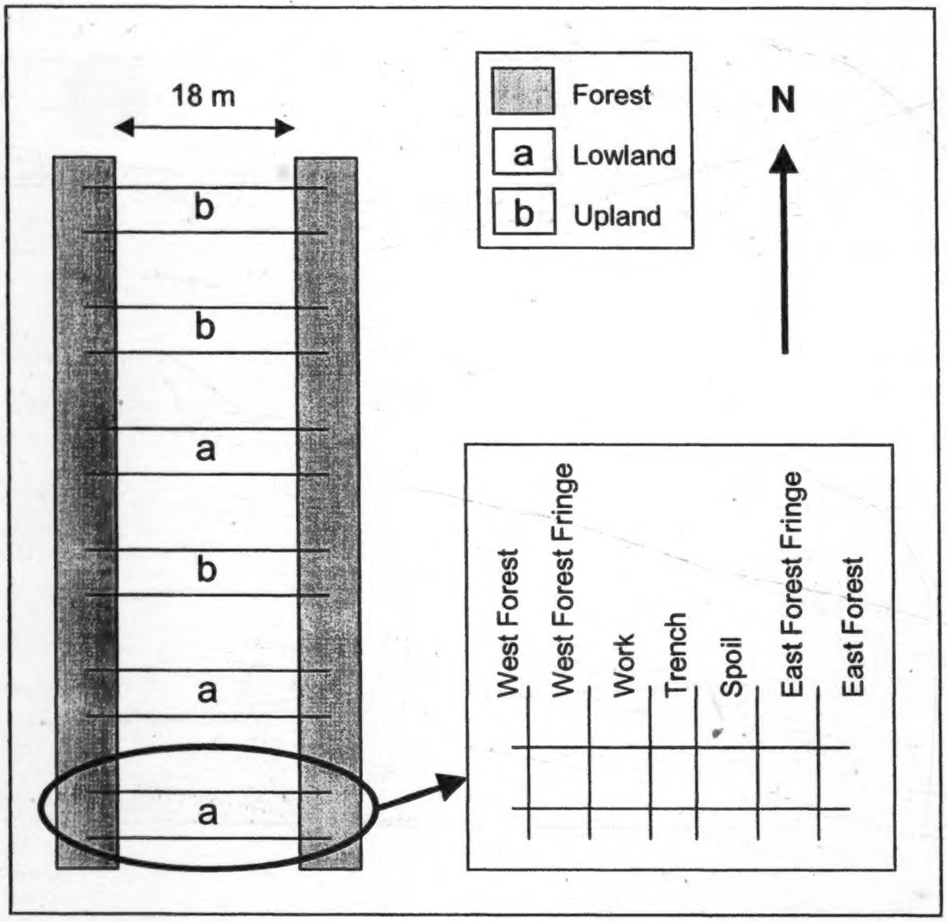
18 m
Forest
a Lowland
b Upland
N
b
b
a
b
a
a
West Forest
West Forest Fringe
Work
Trench
Spoil
East Forest Fringe
East Forest

Figure 2.2. Schematic of lateral pipeline peatland site. Three blocks (a) are topographic lows and three blocks (b) are topographic highs. Blocks were not seeded. The enlarged block shows the pipeline installation treatments.

# III. EFFECTS OF PIPELINE INSTALLATION ON A RIGHT-OF-WAY IN THE CENTRAL MIXEDWOOD BOREAL FOREST OF ALBERTA

## 1. Introduction

Traditionally, three pipeline right-of-way (RoW) zones have been recognized: the spoil area, where material from the trench is stored; the trench, where the pipe is buried; and the work area, where the pipe and associated equipment are stored and most vehicular traffic occurs. Numerous studies have confirmed that these pipeline installation zones have various effects on soil and vegetation characteristics of a given area (De Jong and Button 1973; Culley et al. 1982; Wishart 1983; Naeth et al. 1987; Naeth 1997; Petherbridge 2000; Soon et al. 2000a; Soon et al. 2000b; Ostermann 2001).

Naeth et al. (1987) found that on Solonetzic soils under native range, surface bulk density increased after installation. Trenching increased surface clay content, while decreasing surface silt content. Incorporation of clay material from the trenching operation was also noted by Hardy Associates Ltd. (1983). Clay could be found across all RoW zones. On undisturbed soils, Naeth et al. (1987) found that bulk densities increased with depth, whereas on the trench, they decreased with depth. Naeth et al. (1987) also found that organic carbon was significantly lower on the trench than the undisturbed prairie. Soil pH increased with depth in the undisturbed prairie but was relatively constant with depth on disturbed sites. The majority of these findings are supported by research conducted near Sarnia, Ontario on oil pipeline RoW installed between 1956 and 1973 (Culley et al. 1982); many of the same processes occurred regardless of the soil type.

On the RoW near Sarnia, crop yields, which were monitored from 1976 to 1980, were substantially reduced on the trench and work zones compared to an undisturbed control in all years except 1978 (Culley et al. 1982). Research on two RoW in southern Alberta showed conflicting results. On one RoW, productivity significantly decreased but on the other it did not (Ostermann 2001). Significant differences were also found in productivity in the various RoW zones under grazing conditions. Although plant species did not respond the same way on the two RoW, the RoW zones significantly affected species composition (Ostermann 2001).

## 2. Research Objectives

The research objective was to determine the effect of pipeline installation and reclamation on soil and vegetation parameters in the central mixedwood boreal forest of Alberta. Specific objectives were to:

1) Compare soil characteristics (total organic carbon, organic matter, nitrogen, phosphorus, potassium, electrical conductivity, pH, bulk density, penetration resistance and soil particle size distribution) within the various zones of seeded and natural recovery RoW.
2) Compare plant community characteristics (bare ground, litter cover, and live cover by species) within the various zones of seeded and natural recovery RoW.

## 3. Materials and Methods

### 3.1 Site Description

The study site is located in the central mixedwood subregion of the boreal forest natural region near Whitecourt, Alberta (Achuff 1994). Mean long term summer (April to September) temperature is 11.8 °C and mean long term winter (October to March) temperature is -6.0 °C. Mean total annual precipitation is 577.7 mm (Table 2.1). The dominant landforms of the area include ground moraine, hummocky moraine, aeolian dunes, sand outwash plains and organic deposits (Alberta Environmental Protection 1998). Reference vegetation of the area includes *Populus tremuloides* Michx (trembling aspen), *Picea mariana* Mill (black spruce) and *Picea glauca* Moench (white spruce) forests. Reference soils of the area are gray luvisols (Alberta Environmental Protection 1998).

The site is part of the Alliance Pipeline Ltd. mainline system site and starts at kilometer post (KP) 476.1 and ends at KP 479.5 of mainline spread 4W developed by The Alliance Pipeline Ltd (Figure 3.1). Within the 3.4 km stretch, the site crosses parts of NE/NW/SE 7-60-11, SW/SE 8-60-11 and NE 5-60-11 all of which are W5M. The site is within a mature mixed stand of *Populus tremuloides*, *Picea glauca* and *Pinus contorta* Douglas (lodgepole pine) (Pockar 2002). The area is dominated by orthic gray luvisols, which have been described as well-developed, platy Ae horizons overlying Bt horizons with moderate to strong blocky mesostructure, and calcareous C horizons (Howitt and Pawluk 1985). A soil survey commissioned by Alliance Pipeline Ltd. indicated that the site soil was duff over silty clay.

A second study site was located in a lowland area of the lower foothills subregion of the foothills natural region near Fox Creek, Alberta (Achuff 1994). The nearest Environment Canada weather station is located in Whitecourt and therefore the climate data is assumed to be the same as for the mainline site (Table 3.1). The dominant landforms of the area include morainal veneer over rolling bedrock, organic deposits and bedrock output (Alberta Environmental Protection 1998). Reference vegetation of the area includes *Populus tremuloides*, *Populus balsamifera*, *Picea mariana*, *Picea glauca*, *Pinus contorta* and *Betula papyrifera* Marsh. (white birch) forests. Reference soils of the area are gray luvisols (Alberta Environmental Protection 1998). This site starts at KP 6.45 and ends at KP 8.1 of the Two Creeks lateral pipeline, located south of the Chickadee Creek Crossing (Figure 3.2). Within the 1.65 km stretch, the site crosses parts of SE 7-62-15 and NW/SW/SE 6-62-15 all of which are W5M. The site is primarily located within a mature *Picea mariana* lowland with a small upland portion dominated by *Pinus contorta* (Pockar 2002).

Both seeded and natural recovery portions of the mainline pipeline RoW had the same logging, soil handling, pipeline installation and recontouring history. The site was logged during winter 1999 and construction occurred during winter 2000. The mainline pipeline had a 32 m RoW cleared and the 914 mm pipeline was installed in a 2 m wide trench that was dug with a trenching wheel. The site runs west to east, then turns and runs northwest to southeast with the RoW north of the trench making up the work side and the RoW south of the trench making up the spoil side.

The Two Creeks lateral is a former seismic line that was widened to 18 m to allow for a 1 m wide trench and installation of a 168 mm pipeline. Clearing was done in winter 1999 and construction followed in winter 2000. Final cleanup was completed in winter 2001 but due to washouts and a sunken ditch, remedial work was done in January 2002. The remedial work involved a dozer back blading over the trench area (Hunter 2002). The site had not been seeded but mature, headed out grass was observed during a field survey in spring 2002, and was likely already established on the original seismic line. Direct comparison between the mainline and lateral sites cannot be made due to differences in antecedent site conditions.

## 3.2 Experimental Design and Treatments

Due to the linear nature of the study site, unequal lengths of revegetation treatments, and fixed pipeline RoW treatments, a split plot on a complete block design was used on the mainline mixedwood site. The study site was divided into two treatment areas, seeded and natural recovery. Three blocks were established within the seeded treatment and six blocks within the natural recovery. The number of blocks within the seeded and natural recovery treatments was based on the length of each treatment and availability of representative locations (e.g., flat terrain, no recent disturbance). Blocks were selected primarily to reduce topographic effects and secondarily, to eliminate areas of abnormal vegetation cover. Abnormal vegetation cover was defined as areas of excessively high or low cover or areas with an abnormally high proportion of invasive species. To achieve this, blocks were established in areas that were topographically neutral and had representative vegetation cover as defined by abundance and composition.

The seeded treatment was approximately 1 km long. Each of the three blocks was 15 m wide and extended from the shoulder of the adjacent road, across the full 32 m RoW and 5 m into the adjacent forest. Within each block there were seven pipeline installation treatments. These included (width in brackets) south forest (5 m), south forest fringe (3 m), spoil (14 m), trench (2 m), work (10 m), shoulder fringe (3 m) and shoulder (3 m) (Figure 2.1). This section was broadcast seeded in winter 2000 at a rate of 14 kg ha$^{-1}$. The seed mix was selected by Alliance Pipeline Ltd. as suitable for the area based on its previous use at similar locations. The mix included 20% *Poa palustris* L. (fowl bluegrass), 15% *Festuca ovina* L. (Rocky Mountain fescue), 15% *Bromus ciliatus* L. (fringed brome), 15% *Agropyron trachycaulum* (Link) Malte (slender wheatgrass), 15% *Deschampsia caespitosa* (L.) Beauv (tufted hairgrass), 10% *Koeleria macrantha*

(Ledeb.) J.A. Schultes f. (June grass), 5% *Elymus innovatus* Beal (hairy wild rye) and 5% *Oryzopsis asperifolia* Michx. (mountain rice grass).

The natural recovery treatment was approximately 2.4 km long. The southern 500 m of the natural recovery treatment was eliminated as potential block locations because of an erosion problem from heavy equipment brought in to stabilize and recontour the area. Natural recovery blocks were not seeded or fertilized and erosion control strategies were not employed. Each of the six blocks was 15 m wide and extended across the 32 m RoW with 5 m of forest on each side. The pipeline installation treatments were the same as the seeded blocks with the exception that the shoulder and shoulder fringe were replaced with second forest and forest fringe treatments (Figure 3.1).

On the lateral peatland site, there was only a natural recovery treatment as seeding is not standard procedure on lowland areas. However, the site was blocked to separate topographic areas. Three blocks were established on topographic highs, which were *Picea* dominated and three blocks were established on topographic lows, which were *Picea mariana* dominated. Each of the six blocks was 15 m wide and extended across the 18 m RoW with 5 m of forest on each side. Within each block there were seven pipeline RoW treatments including (width in brackets) east forest (5 m), east forest fringe (2 m), work (9 m), trench (1 m), spoil (4 m), west forest fringe (2 m) and west forest (5 m) (Figure 3.2).

## 3.3 Field and Laboratory Measurements

### 3.3.1 Soil

In July 2002, soil samples were taken from the center of each RoW treatment at 10 cm increments to a depth of 30 cm using a hand auger. Seven samples per depth per block were collected. Samples were stored in Ziploc plastic bags and kept cool until they were analyzed for chemical properties. No soil samples were taken at the lateral line site as this was primarily used for vegetation assessment.

Organic carbon was determined using a modified Walkley-Black method (Enviro-Test 2001) where soil is treated with potassium dichromate ($K_2Cr_2O_7$) and sulfuric acid

($H_2SO_4$) to oxidize the organic matter (Carter 1993; Enviro-Test 2001). The remaining dichromate is back titrated with ferrous ammonium sulfate [Fe $(NH_4)_2(SO_4)_2$]. Organic matter content was calculated by assuming organic matter was 58% carbon (Van Bemmelen Factor).

To determine soil electrical conductivity and pH, samples were oven dried and ground to 2 mm. Soil was thoroughly mixed and added to deionized water to form a saturated paste, in which measurements were taken with conductivity and pH meters (McKeague 1978; Carter 1993; Enviro-Test 2001). This method has been effective for forest soils (Tremblay et al. 2002).

In addition to organic matter, electrical conductivity and pH, appropriate nutrient levels are critical for plant growth. Of particular importance are the macronutrients. This study assessed three macronutrients, specifically their plant availability. Available nitrate-nitrate nitrogen was determined using the cadmium reduction method (Carter 1993; Enviro-Test 2001). This method involves reducing nitrate to nitrite by passing the sample through a copperized cadmium column. The nitrite is then reacted with a diazotizing reagent (sulfanilimide) and a coupling reagent [N-(1-naphthyl)-ethylenediamine dihydrochloride]. The resulting solution is measured colorimetrically at 520 nm (Martin 1993; Enviro-Test 2001). This method is very sensitive and is not affected by organic matter and soil cations (Keeney and Nelson 1982). Available phosphate in the form orthophosphate and available potassium were determined using the modified Kelowna method (Enviro-Test 2001). The extracting solution contains 0.025 M HOAc, 0.25 M $NH_4Oac$ and 0.015 M $NH_4F$ at pH 4.5. Orthophosphate reacts with the ammonium molybdate and antimony tartrate to form a complex that is then reduced with ascorbic acid and measured colorimetrically at 880nm (Enviro-Test 2001). To determine the available potassium, the soil extract is mixed with internal standards (lithium nitrate, nitric acid and lanthanum oxide) and measured using a flame photometer (Enviro-Test 2001). Light intensity is measured at 768 nm (Enviro-Test 2001).

In June 2003, further soil testing was conducted to determine bulk density, penetration resistance and particle size. An Uhland corer was used to take a soil sample from the center of each RoW treatment at 10 cm increments to a depth of 30 cm. Samples were oven dried at 105 °C to constant weight. Weights were determined using an AND Scientific Balance (Model FY 3000). Three penetration resistance measurements were taken in each RoW treatment at depths of 0, 5, 10, 20, 30 and 40 cm using a proving ring penetrometer with a 30° circular cone with a 13 mm diameter at the base. Particle size analysis was performed by Enviro-Test Laboratories of Edmonton, Alberta using the hydrometer method (Kalra and Maynard 1991).

### 3.3.2 Vegetation

A vegetation assessment was conducted on the mixedwood and peatland sites during the last week of June 2002. By assessing the vegetation at this time, both early and late species could be identified. Within each of the pipeline RoW treatments of all nine blocks, four randomly placed 0.1 $m^2$ quadrats (20 x 50 cm) were assessed for percent bare ground, litter and live cover by species. This size of quadrat was chosen because the dominant vegetation was grasses and small shrubs and it has been used in similar vegetation surveys (Daubenmire 1959; Larson and Larson 1987). A species area curve was developed to confirm that four quadrats were sufficient per treatment. A walk through survey was performed to record the presence of species not observed in the quadrat assessments. This survey involved walking across the RoW perpendicular to the pipeline and visually inspecting the site. Walking paths were spaced every 3 m. In June 2003, when the second set of soil samples were collected, average root depths were visually assessed by washing the face of the hole left from the Uhland corer.

## 3.4 Statistical Analyses

The data were assessed for normality using the Shapiro-Wilk test and were normal. Within the seeded and natural recovery treatments an analysis of variance (ANOVA) was performed on the vegetation parameters and three key soil parameters. The three key (most likely to affect plant parameters) soil parameters that were analyzed with inferential statistics were organic matter, pH and bulk density. Right-of-Way zones were the treatment factor and the data were analyzed as though the RoW treatments were randomly located within the blocks. Although the lack of randomization introduces bias and violates an assumption of the ANOVA test, it is believed that the bias will be small when compared to the treatment effect resulting from the pipeline installation (Soon et al. 2000b). The ANOVA was performed using a general linear model (GLM) within the SAS statistical program. Where a significant difference was detected ($p \leq 0.05$), a Tukey post-hoc multiple comparison test was done (Zar 1999).

All parameters measured were not statistically analyzed to avoid data dredging (Blenis 2004). There were ten soil parameters measured across three depths and one parameter measured across six depths. Had all of these variables been analyzed statistically there would have been 36 variables and the chance of rejecting a true null hypothesis (Type 1 Error) increases. As the number of variables analyzed increases, statistical power decreases.

# 4. Results and Discussion

## 4.1 Soils

Bulk density of soils in the upper 10 cm ranged from 0.63 Mg $m^{-3}$ on the south forest fringe to 1.19 Mg $m^{-3}$ on the spoil on seeded treatments and from 0.47 Mg $m^{-3}$ on the north forest fringe to 1.21 Mg $m^{-3}$ on the south forest fringe of the natural recovery treatment (Tables 3.2 and 3.3). The upper limits of 1.21 and 1.19 Mg $m^{-3}$ indicate that some compaction is occurring compared to undisturbed conditions but the bulk density would not be considered restrictive to root growth for most species (Naeth et al. 1991). The vertically penetrating roots observed at 30 cm, also indicate little negative response to bulk density.

RoW zone had no statistically significant effect on upper 10 cm bulk densities in the seeded treatments. However, under natural recovery, one forest zone was significantly different from the RoW zones. Highest bulk density would normally be expected on the trench or work area where heavy equipment traffic is concentrated. However, the upper 10 cm measurement is mainly on topsoil that was replaced after recontouring and therefore less subjected to compacting equipment. In general, bulk density increased with depth on both revegetation treatments and was not high enough to cause root growth problems. Below 10 cm, values were similar regardless of RoW zone. These bulk density values are similar to those reported by Soon et al. (2000b) and Ostermann (2001). The current study supports work done on other soils indicating that pipeline installation activities increase surface bulk densities compared to undisturbed sites (Culley et al. 1982; Naeth et al. 1987).

At the surface and shallow depths, penetration resistance was lowest in the undisturbed forest treatments but below 20 cm there was no trend. This was as expected based on construction activity effects. Soon et al. (2000b) recognized that this may be due to intentional surface compaction over the trench but a lack of settling of the overburden material at greater depths. These data are also consistent with those found by Naeth et al (1987). In all cases, values on the RoW were often above the 2 MPa suggested for the threshold at which plant roots would be affected (Naeth et al. 1991). However, as indicated in the previous section, roots were not visibly restricted by these values.

Organic matter was not statistically significantly different in the upper 10 cm between the RoW zones on either seeded or natural recovery treatments (Tables 3:2 and 3.3). These non-significant differences may, however, have biological significance, specifically in the seeded treatment where organic matter ranged from 3.0% on the work zone to 6.0% on the south forest fringe. A 3% difference in organic matter could affect the plant community that develops. At this site, 10 of the 16 species found on the work area of the seeded treatment were native and did not visually appear to be affected from the lower amount of organic matter. These differences between pipeline and forest areas suggest the duff salvaging and topsoil handling procedures were effective in preserving organic matter and also that topsoil and duff were spread back across the site with some losses over the trench and the work area.

As expected, organic matter generally decreased steadily with depth. The largest decrease was between the first two depth increments compared to the last two indicating topsoil and duff were not incorporated with deeper soil horizons. Results were similar to a study on gray wooded soil near Beaverlodge, Alberta, where Soon et al. (2000b) reported 7.7% organic matter in the upper 10 cm and 2.8% at 10 to 20 cm. The range of values across the RoW treatments and with depth were also comparable to those on a pipeline RoW installed on an orthic brown chernozem near Hardisty, Alberta (Petherbridge 2000).

There were statistically significant differences in pH between RoW treatments of both seeded and natural recovery treatments at 0 to 10 cm (Tables 3.2 and 3.3). On the seeded treatment, pH ranged from 5.4 on the south forest zone to 7.9 on the work zone. On natural recovery treatments, pH ranged from 5.4 on the north forest fringe to 7.65 on the spoil. The only biologically significant difference occurred between the forest treatments and the RoW treatments. Soil pH was lowest on the forest treatments at all depths, near 5.5, which is close to that reported by Howitt and Pawluk (1985) on undisturbed gray luvisols within the boreal forest region and by Soon et al. (2000 b) for a Braeburn silt loam near Beaverlodge, Alberta. The low pH of the forest zones are common and result from microbial production of organic acids within the litter matter that is deposited annually. The disturbed areas were obviously receiving little litter input from the adjacent forest and therefore did not have an acidified upper horizon. The pH of the disturbed zones were well within the range commonly considered acceptable for plant growth. The lower values on the undisturbed zones are within a homeostatic range for forest species.

Electrical conductivities of the disturbed RoW treatments were higher than the forest treatments on both seeded and natural recovery treatments (Tables 3.2 and 3.3). Despite this, their range is well below the critical level for plant growth. Electrical conductivity was not expected to become a problem in this area because it receives moderate amounts of precipitation. On the natural recovery treatment, at all three depths, values were lowest on the forest treatments (Table 3.3). Although there was only one forest treatment on the seeded section, the same trend was evident (Table 3.2).

On both seeded and natural recovery treatments, nitrate levels remained relatively constant among depths. Across RoW treatments, nitrate was consistently lower on the forest and forest fringes than the RoW treatments. The exception was the seeded south forest fringe and south forest treatment at 20 to 30 cm (Table 3.3). Although determining water tables and soil moisture conditions were not objectives of this research, on the forest zones, the water table was encountered several times and the overall soil moisture was greater. Denitrification may have been occurring at depths where conditions were anaerobic. Considering that nitrate is soluble, surface nitrate may have been leached to depths and then undergone denitrification. Moisture in the disturbed zones was visually lower than in the forest and the water table was never encountered; therefore, the likelihood of nitrification occurring is greater. The dominant leguminous species such as clovers and vetch may fix nitrogen, providing nitrogen containing organic compounds to undergo mineralization with production of ammonium which can then undergo nitrification to produce nitrate. Although the legumes would have only been established for two years, they could be a contributing factor to high nitrate levels, although it is not known for sure that they are nodulated.

Two very strong trends were seen with phosphate: it decreased with depth and increased in proximity to the forest treatments. There were no strong trends for available potassium on either vegetation treatment.

Overall, soil chemical and physical parameters measured were as expected for boreal forest soils and support the findings of other pipeline research. An important finding is that it appears soil conditions across the RoW were favorable for plant growth. In past research, pipeline installation altered soil chemical and physical properties and some of these alterations have been linked to reduced yields in agricultural settings (De Jong and Button 1973; Culley et al. 1982; Naeth et al 1987). These studies point out particular issues associated with various RoW zones such as compaction in the work area or increased clay content caused by improper soil handling of the excavated subsoil material. Other issues involving reduced organic matter levels across the RoW and alteration in pH and electrical conductivity with depth have been reported. Based on more current research on recently installed pipelines, improved soil management procedures are resulting in fewer negative impacts on soil. Petherbridge (2000), reporting on a large (61 cm) pipeline constructed near Hardisty, Alberta, indicated that installation resulted in only slight changes from undisturbed conditions in soil parameters such as electrical conductivity, pH and organic carbon for RoW zones (spoil, trench and work) and depth. Other recent studies indicate pipeline installation is still having lasting effects on certain soil conditions, particularly soil strength (Ostermann 2001; Soon et al. 2000 b).

## 4.2 Vegetation

### 4.2.1 Mixedwood Forest

On seeded treatments, live cover was not significantly different among RoW treatments and ranged from 36.8% on the work treatment to 49.9% on the trench (Table 3.4). The forest and forest fringe had slightly less live cover than the trench. As expected, bare ground was inversely related to live cover ranging from 1.7% in the south forest to 44.7% on the work treatment. The low bare ground in the south forest corresponded to very high litter cover of 53.8% litter, nearly twice that of any other RoW treatment and significantly different from all other RoW treatments. The lowest litter cover was found on the work treatment and corresponded to the highest bare ground.

Under natural recovery, live cover ranged from 19.2% on the north forest to 49.6% on the trench (Table 3.4). The work, trench and spoil all had higher cover than the four remaining RoW treatments but the differences were not significant. The bare ground on both of the forest treatments was significantly less than the other five RoW treatments but not significantly different from each other. Bare ground in all treatments, except the forests, differed by less than 7%. Litter was significantly higher on both forest treatments than on the remaining RoW treatments. There was no significant difference between any of the other five RoW treatments but the general trend was a decrease in litter from the forests to the trench.

Although RoW treatments were mostly not statistically different, it is apparent that on mixedwood natural recovery there is an ecologically significant difference between the north forest and the other RoW treatments. The north forest has 15% less ground cover than the RoW treatment with next lowest cover. The low cover is balanced by very high litter; thus, there is little potential for erosion and less potential for invasion by non-native species. The forest floor exposure to the drying conditions associated with the afternoon sun may reduce cover. The other forest treatments on the natural recovery and seeded treatments are not exposed to afternoon sun and have approximately double the cover. All forest treatments would reflect the lower cover characteristic of a mature canopy forest floor. The cover was measured at the herbaceous canopy level and hence would not account for the large woody cover and canopy of the forest.

Petherbridge (2001) found that undisturbed prairie had significantly more live cover than RoW treatments one year after installation; however, after the second growing season, differences were no longer significant. Ostermann (2001) also found no significant differences between disturbed RoW treatments; however, this research also did not show a significant difference between the undisturbed prairie and the disturbed RoW treatments. Older pipeline research conducted on various soil types in agricultural areas in Alberta and Ontario indicates site specific effects on productivity (De Jong and Button 1973; Culley et al. 1982)

Species richness declined steadily with intensity of disturbance on the seeded treatment from 32 species in the south forest to 16 species on trench and work zones (Table 3.5). Accompanying this decline was an increase in aggressive non-native species such as *Trifolium* and *Melilotus* and weedy species such as *Taraxacum officinale* Weber (dandelions) and *Sonchus arvense* L. (perennial sow thistle). There were no non-native species found in the south forest and three were found in the south forest fringe. In contrast, nearly half of the species on the other RoW treatments were non-native. There were also differences in type of plant species (Table 3.5). In the forest, there were only two grass, sedge or horsetail species. The remainder of the 32 species were approximately half forbs and half shrubs and trees. In contrast, a third of the species on the three remaining RoW treatments were grasses, sedges and horsetails. This highlights the opportunistic nature of the aggressive and weedy species and their ability to colonize rapidly on disturbed soils. An annual cover crop might reduce this colonization opportunity if natural recovery is used. These results indicate that the ideal situation to use natural recovery is where there are few aggressive, weedy or invasive species in the surrounding area. Although it would be hard to find an area in the province that has not been disturbed by some type of development, that situation (few invasive species nearby) would be a contributing factor to successful natural recovery.

In the south forest of the seeded treatment, no seeded species were found compared to the south forest fringe where five seeded species were found (Table 3.5). However, of the five species, only one, *Agropyron trachycaulum*, was in the top five for cover. At 4.0% cover, it was the fifth most dominant species. *Cornus canadensis* L. (bunchberry) was the dominant species on the south forest fringe and the second most dominant in the south forest. On all three other RoW treatments, *Trifolium pratense* L. (red clover) was the dominant species while *Agropyron trachycaulum* was the second most dominant. On those three RoW treatments, Agropyron *trachycaulum* was the only seeded species that had 10% or more cover. Although there were other seeded species present, their levels of cover were all below 2%. Of the eight species seeded, *Bromus ciliatus* and *Oryzopsis asperifolia* were not found on any RoW treatment. The absence of these species was likely the result of poor seed quality or their inability to compete with the other plants. If the seed quality was good (seed certificates were not available) then it may be concluded that it is not advantageous to seed those species under similar conditions.

The north forest, north forest fringe, south forest fringe and south forest on the natural recovery treatment had 30, 32, 33 and 31 species on them, respectively (Table 3.6). This is in contrast to the work, trench and spoil treatments, which had a total of 20, 24 and 25 species on them, respectively. Although there is a decline from the periphery to the center of the RoW, the decline is not as severe as that seen on the seeded treatment. Although the natural recovery treatment was not seeded, species that were in the seed mix for the seeded treatment were identified as seeded to determine if the native seed mix actually represented the early successional species seen in natural recovery. The only two species that showed up on the natural recovery treatment that were common to the seed mix were *Elymus innovatus* and *Poa palustris.* Low cover of these species was found on the north forest fringe and south forest fringe treatments, respectively. This suggests that if seeding is to continue as common practice, and seed mixes are to be marketed as native for forested areas, the seed industry needs to expand the types of plant that are available as seed or seedlings.

On both revegetation treatments on the mixedwood site, species richness was greatest on the undisturbed forest treatments and decreased towards the trench treatment. The disturbed RoW treatments on the natural recovery treatment had greater species richness than disturbed treatments on the seeded treatment. This is strong indication that seeding prevents some native species from establishing. This finding is supported by Ealey and Virgl (2002) and Petherbridge (2000).

On both revegetation treatments, many shrubs and trees were limited to growth in the forest. Such observations indicate that a site does not have to be seeded to prevent woody species from rapidly encroaching towards the center of the RoW. This is not surprising as often the dominant species in a soil propagule bank are not the species that are seen growing in adjacent communities (Granström 1986). Seeded species did not rapidly move from the seeded area into the adjacent undisturbed community. No seeded species were found in any of the forest treatments.

### 4.2.2 Peatland

Mean live cover on topographic low treatments of the peatland site ranged from 22.5% on the trench to 78.5% on the west forest (Table 3.7). The highest bare ground in the forest was 5.0% on the west forest, while the trench had 69.7%. Both forest fringes on topographic lows had less cover than work and spoil treatments. Mean live cover on the topographic highs ranged from 8.7% on the trench to 93.6% on the west forest treatment. There was a relatively symmetrical decline in cover from the forest treatments towards the trench. Bare ground was extremely variable across the RoW, ranging from 0.0% on both forest treatments to 89.5% on the trench.

The forest treatments on topographic lows had four dominant species: moss species, *Betula glandulosa* Michx (bog birch), *Ledum groenlandicum* Oeder (common labrador tea) and *Rubus chamaemorus* L (cloudberry) (Table 3.8). On all of the other pipeline installation treatments, except the trench, *Calamagrostis canadensis* Michx (marsh reed grass) was one of the most dominant species. On topographic highs, over the forest and forest fringe treatments, *Ledum groenlandicum* and *Vaccinium myrtilloides* Michx (blueberry) were the dominant species. Across the other three RoW treatments, there did not appear to be common dominant species or even a common type of species (Table 3.9).

Although the peatland data were not statistically analyzed, the trends across the RoW were not the same as those on the mixedwood site. A key difference is the amount of live cover on the trench. On both the topographic low and topographic high treatments, live cover was extremely low. The explanation for this is that remedial clean-up work was done in January 2002 that involved scraping excess material from the roach of the trench with a bulldozer and placing it on the work treatment. This action makes it very difficult to assess the data from the trench and work treatments. One trend similar to that of the mixedwood site is that forest treatments exposed to the afternoon sun (east forest treatment) on the both the topographic low and high treatments had less forest floor live cover than their counterpart on the west side of the RoW. Again, this is an indication that drier sites result in lower live cover.

In both topographic lows and highs, non-native species were uncommon (Tables 3.8 and 3.9). *Festuca* sp. and *Trifolium* sp., in very small amounts, were the only non-native species found in any of the treatments. This indicates that if sites are not seeded, non-native species may be uncommon and the plant community will more closely resemble the undisturbed plant community.

## 5. Summary and Conclusions

- There are no significant differences in vegetation or soil parameters between pipeline RoW treatments on either seeded or natural recovery treatments on the mixedwood forest site.
- Live vegetation cover did not vary significantly across RoW treatments of the seeded and natural recovery treatments on the mixedwood forest site.
- Species richness decreased from the undisturbed treatments towards the trench on both the mixedwood forest and peatland sites.
- On the mixedwood forest site, seeded species were not invading the adjacent forest after two years and woody species were not rapidly invading the disturbed RoW treatments.
- Soil salvaging and handling procedures used on the mixedwood site appear to be preserving soil quality and maintaining a considerable portion of seeds and propagules near the surface.

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Table 3.1. Climate data for the Environment Canada weather station near Whitecourt, Alberta.

| | 1971-2001 | 2001 | 2002 | 2003 |
|---|---|---|---|---|
| Summer (April to September) | | | | |
| Daily Mean Temperature (°C) | 11.8 | 12.0 | 12.6 | 11.6 |
| Minimum Typical Temperature (°C) | 5.0 | 5.8 | 4.1 | 5.5 |
| Maximum Typical Temperature (°C) | 17.5 | 18.2 | 16.6 | 17.6 |
| Winter (October to March) | | | | |
| Daily Mean (°C) | -6.0 | -9.2 | -5.3 | -5.8 |
| Minimum Typical Temperature | -11.1 | -9.2 | -9.9 | -10.7 |
| Maximum Typical Temperature | -0.9 | 0.6 | -0.8 | -0.9 |
| Annual Mean (°C) | 2.6 | 3.9 | 2.5 | 2.9 |
| Annual Rainfall (mm) | 440.3 | 393.9 | 204.8 | 208.7 |
| Annual Snowfall (cm) | 178.1 | 105.0 | 198.0 | 253.4 |
| Total Annual Precipitation (mm) | 577.7 | 471.4 | 365.3 | 407.0 |

The weather station is located at 54° 8' N, 115° 47' W, 782.40 masl (Environment Canada 2004).

Table 3.2. Summary of soil parameters from the seeded treatment in the mixedwood site.

| Parameter | Depth (cm) | Work | Trench | Spoil | South Forest Fringe | South Forest |
|---|---|---|---|---|---|---|
| Bulk Density (Mg m$^{-3}$) | 0-10 | 0.94 a<br>(0.32) | 0.9 a<br>(0.06) | 1.19 a<br>(0.23) | 0.63 a<br>(0.14) | 0.88 a<br>(0.20) |
| Bulk Density (Mg m$^{-3}$) | 10-20 | 1.11<br>(0.19) | 1.04<br>(0.14) | 1.28<br>(0.24) | 1.19<br>(0.27) | 1.16<br>(0.05) |
| Bulk Density (Mg m$^{-3}$) | 20-30 | 1.43<br>(0.08) | 1.14<br>(0.08) | 1.32<br>(0.17) | 1.42<br>(0.10) | 1.28<br>(0.05) |
| Penetration Resistance (MPa) | 0 | 2.61<br>(0.89) | 2.72<br>(1.00) | 2.75<br>(2.90) | 2.06<br>(0.97) | 1.75<br>(1.23) |
| Penetration Resistance (MPa) | 5 | 3.69<br>(1.84) | 3.14<br>(0.94) | 2.33<br>(0.55) | 2.17<br>(0.14) | 1.25<br>(0.87) |
| Penetration Resistance (MPa) | 10 | 3.75<br>(1.75) | 4.14<br>(0.84) | 3.28<br>(1.14) | 2.25<br>(0.14) | 2.25<br>(0.80) |
| Penetration Resistance (MPa) | 20 | 4.00<br>(1.82) | 4.44<br>(0.60) | 3.42<br>(1.12) | 2.69<br>(0.54) | 3.36<br>(0.42) |
| Penetration Resistance (MPa) | 30 | 4.06<br>(1.72) | 4.58<br>(0.51) | 3.72<br>(1.06) | 2.78<br>(0.54) | 3.83<br>(0.80) |
| Penetration Resistance (MPa) | 40 | 4.33<br>(1.24) | 5.00<br>(0.17) | 3.75<br>(1.09) | 2.86<br>(0.39) | 4.11<br>(1.04) |

Table 3.2. Summary of soil parameters from the seeded treatment in the mixedwood site (continued).

| Parameter | Depth (cm) | Work | Trench | Spoil | South Forest Fringe | South Forest |
|---|---|---|---|---|---|---|
| Sand (%) | 0-10 | 35.33<br>(7.37) | 32.00<br>(4.36) | 33.67<br>(3.79) | 33.67<br>(4.16) | 34.00<br>(2.00) |
| Sand (%) | 10-20 | 38.67<br>(6.03) | 25.67<br>(22.01) | 37.00<br>(11.14) | 36.33<br>(11.24) | 30.67<br>(9.87) |
| Sand (%) | 20-30 | 40.00<br>(11.53) | 22.00<br>(13.89) | 34.67<br>(13.05) | 31.33<br>(12.50) | 30.00<br>(16.52) |
| Silt (%) | 0-10 | 30.00<br>(6.56) | 27.00<br>(4.00) | 29.67<br>(3.22) | 31.00<br>(5.29) | 35.33<br>(7.64) |
| Silt (%) | 10-20 | 26.00<br>(3.61) | 27.00<br>(9.54) | 25.33<br>(4.73) | 32.67<br>(12.86) | 29.00<br>(6.00) |
| Silt (%) | 20-30 | 24.33<br>(3.06) | 29.33<br>(4.04) | 21.33<br>(1.16) | 35.67<br>(8.51) | 30.33<br>(7.51) |
| Clay (%) | 0-10 | 34.33<br>(1.16) | 40.67<br>(1.16) | 36.67<br>(0.58) | 35.00<br>(1.00) | 30.67<br>(6.51) |
| Clay (%) | 10-20 | 35.67<br>(3.06) | 47.67<br>(18.58) | 37.67<br>(7.23) | 31.00<br>(10.44) | 40.33<br>(6.11) |
| Clay (%) | 20-30 | 35.67<br>(7.64) | 48.67<br>(12.66) | 44.33<br>(12.86) | 33.00<br>(14.00) | 40.00<br>(11.53) |

Table 3.2. Summary of soil parameters from the seeded treatment in the mixedwood site (continued).

| Parameter | Depth (cm) | Work | Trench | Spoil | South Forest Fringe | South Forest |
|---|---|---|---|---|---|---|
| Organic Matter (%) | 0-10 | 3.03 a<br>(0.67) | 3.67 a<br>(2.32) | 4.73 a<br>(0.85) | 6.00 a<br>(1.81) | 5.53 a<br>(3.16) |
| Organic Matter (%) | 10-20 | 2.30<br>(0.56) | 2.83<br>(1.89) | 2.93<br>(0.35) | 2.43<br>(1.02) | 2.70<br>(0.53) |
| Organic Matter (%) | 20-30 | 2.57<br>(1.10) | 2.47<br>(1.29) | 1.40<br>(0.60) | 2.10<br>(0.46) | 1.80<br>(0.56) |
| Electrical Conductivity (dS m$^{-1}$) | 0-10 | 0.17<br>(0.06) | 0.27<br>(0.15) | 0.23<br>(0.06) | 0.17<br>(0.06) | 0.13<br>(0.06) |
| Electrical Conductivity (dS m$^{-1}$) | 10-20 | 0.20<br>(0.00) | 0.20<br>(0.00) | 0.23<br>(0.06) | 0.17<br>(0.06) | 0.10<br>(0.00) |
| Electrical Conductivity (dS m$^{-1}$) | 20-30 | 0.20<br>(0.10) | 0.20<br>(0.00) | 0.17<br>(0.06) | 0.10<br>(0.00) | 0.13<br>(0.06) |
| pH | 0-10 | 7.90 a<br>(0.35) | 7.27 ab<br>(0.38) | 7.63 ab<br>(0.23) | 7.07 b<br>(0.50) | 5.37 c<br>(0.55) |
| pH | 10-20 | 7.70<br>(0.44) | 7.67<br>(0.32) | 7.47<br>(0.12) | 6.77<br>(0.64) | 5.87<br>(0.72) |
| pH | 20-30 | 7.80<br>(0.27) | 7.73<br>(0.21) | 7.60<br>(0.53) | 6.53<br>(0.45) | 6.30<br>(1.31) |

Table 3.2. Summary of soil parameters from the seeded treatment in the mixedwood site (continued).

| Parameter | Depth (cm) | Work | Trench | Spoil | South Forest Fringe | South Forest |
|---|---|---|---|---|---|---|
| Nitrogen (mg kg$^{-1}$) | 0-10 | 2.87<br>(0.40) | 2.53<br>(0.25) | 2.37<br>(0.60) | 2.43<br>(0.51) | 2.33<br>(0.29) |
| Nitrogen (mg kg$^{-1}$) | 10-20 | 2.60<br>(0.17) | 2.53<br>(0.25) | 2.70<br>(0.17) | 2.43<br>(0.40) | 2.53<br>(0.25) |
| Nitrogen (mg kg$^{-1}$) | 20-30 | 2.43<br>(0.40) | 2.33<br>(0.29) | 2.43<br>(0.51) | 3.70<br>(1.15) | 2.63<br>(0.58) |
| Phosphate (mg kg$^{-1}$) | 0-10 | 5.33<br>(1.53) | 11.00<br>(5.57) | 13.00<br>(5.20) | 16.33<br>(9.07) | 19.00<br>(25.16) |
| Phosphate (mg kg$^{-1}$) | 10-20 | 3.33<br>(2.52) | 6.33<br>(3.51) | 4.00<br>(1.73) | 8.67<br>(6.43) | 31.67<br>(53.12) |
| Phosphate (mg kg$^{-1}$) | 20-30 | 2.00<br>(1.00) | 4.33<br>(1.53) | 3.33<br>(3.22) | 2.00<br>(1.73) | 19.33<br>(31.75) |
| Potassium (mg kg$^{-1}$) | 0-10 | 163.67<br>(47.48) | 173.67<br>(43.84) | 178.67<br>(29.94) | 200.00<br>(24.33) | 480.67<br>(349.37) |
| Potassium (mg kg$^{-1}$) | 10-20 | 135.67<br>(77.78) | 158.67<br>(43.19) | 145.67<br>(30.57) | 193.00<br>(55.68) | 263.33<br>(138.15) |
| Potassium (mg kg$^{-1}$) | 20-30 | 177.00<br>(56.63) | 132.00<br>(19.93) | 130.00<br>(23.81) | 226.00<br>(51.64) | 147.00<br>(52.00) |

Means and standard deviations are presented
Treatments that share a letter do not have statistically different means at a p-value of 0.05
N = 3

Table 3.3. Summary of soil parameters from the natural recovery treatment in the mixedwood site.

| Parameter | North Forest | North Forest Fringe | Work | Trench | Spoil | South Forest Fringe | South Forest |
|---|---|---|---|---|---|---|---|
| Db 0-10 cm (Mg m$^{-3}$) | 0.47 a<br>(0.17) | 1.09 b<br>(0.21) | 1.17 b<br>(0.24) | 1.13 b<br>(0.16) | 1.16 b<br>(0.24) | 1.21 b<br>(0.26) | 0.91 ab<br>(0.34) |
| Db 10-20 cm (Mg m$^{-3}$) | 1.21<br>(0.19) | 1.22<br>(0.39) | 1.23<br>(0.41) | 1.47<br>(0.11) | 1.11<br>(0.03) | 1.32<br>(0.22) | 0.99<br>(0.44) |
| Db 20-30 cm (Mg m$^{-3}$) | 1.51<br>(0.30) | 1.13<br>(0.24) | 1.38<br>(0.13) | 1.33<br>(0.23) | 1.25<br>(0.28) | 1.21<br>(0.11) | 1.19<br>(0.32) |
| PR 0 cm (MPa) | 0.61<br>(0.38) | 1.28<br>(0.10) | 1.67<br>(0.30) | 2.25<br>(0.80) | 1.72<br>(0.49) | 1.61<br>(0.57) | 0.58<br>(0.29) |
| PR 5 cm (MPa) | 1.17<br>(0.52) | 2.42<br>(0.73) | 2.83<br>(0.14) | 3.61<br>(1.47) | 2.42<br>(0.30) | 2.44<br>(0.56) | 1.36<br>(1.01) |
| PR 10 cm (MPa) | 2.36<br>(1.11) | 3.28<br>(0.26) | 3.17<br>(0.44) | 4.11<br>(1.03) | 2.72<br>(0.63) | 2.81<br>(0.75) | 2.64<br>(0.54) |
| PR 20 cm (MPa) | 4.14<br>(0.49) | 4.19<br>(0.47) | 3.97<br>(0.85) | 4.36<br>(0.92) | 2.86<br>(0.75) | 3.28<br>(0.54) | 4.08<br>(0.44) |
| PR 30 cm (MPa) | 4.36<br>(0.56) | 4.75<br>(0.17) | 4.19<br>(0.54) | 4.53<br>(0.98) | 3.14<br>(1.04) | 3.31<br>(0.50) | 4.47<br>(0.41) |
| PR 40 cm (MPa) | 4.39<br>(0.60) | 4.78<br>(0.17) | 4.22<br>(0.57) | 4.61<br>(0.97) | 3.28<br>(1.25) | 3.56<br>(0.84) | 4.67<br>(0.52) |

Table 3.3. Summary of soil parameters from the natural recovery treatment in the mixedwood site (continued).

| Parameter | North Forest | North Forest Fringe | Work | Trench | Spoil | South Forest Fringe | South Forest |
|---|---|---|---|---|---|---|---|
| Sand 0-10 cm (%) | 47.67<br>(14.15) | 40.00<br>(0.00) | 34.33<br>(3.06) | 35.67<br>(9.02) | 30.33<br>(9.45) | 33.00<br>(3.61) | 33.67<br>(11.59) |
| Sand 10-20 cm (%) | 34.67<br>(17.10) | 45.67<br>(8.33) | 25.00<br>(18.33) | 34.00<br>(3.61) | 30.00<br>(7.00) | 21.33<br>(5.69) | 25.00<br>(3.46) |
| Sand 20-30 cm (%) | 22.33<br>(16.07) | 35.00<br>(7.00) | 25.67<br>(19.63) | 31.33<br>(10.97) | 28.33<br>(9.82) | 11.00<br>(2.00) | 24.67<br>(4.04) |
| Silt 0-10 cm (%) | 35.33<br>(8.08) | 35.33<br>(9.07) | 35.67<br>(10.69) | 25.67<br>(6.66) | 31.33<br>(4.62) | 29.67<br>(4.93) | 38.67<br>(8.51) |
| Silt 10-20 cm (%) | 35.33<br>(5.69) | 33.33<br>(12.22) | 34.00<br>(11.14) | 33.00<br>(12.29) | 30.00<br>(5.29) | 35.67<br>(6.66) | 45.67<br>(7.51) |
| Silt 20-30 cm (%) | 35.33<br>(7.23) | 39.00<br>(13.45) | 30.00<br>(7.94) | 25.00<br>(3.61) | 29.00<br>(9.54) | 28.33<br>(8.51) | 44.33<br>(10.02) |
| Clay 0-10 cm (%) | 17.67<br>(5.77) | 25.00<br>(8.72) | 30.33<br>(9.02) | 39.33<br>(8.51) | 38.33<br>(13.01) | 37.00<br>(2.65) | 27.67<br>(3.22) |
| Clay 10-20 cm (%) | 30.00<br>(22.52) | 21.00<br>(4.00) | 41.33<br>(16.26) | 33.33<br>(11.59) | 40.00<br>(12.12) | 42.67<br>(7.77) | 29.67<br>(10.07) |
| Clay 20-30 cm (%) | 42.00<br>(22.61) | 26.00<br>(15.72) | 44.33<br>(23.46) | 43.67<br>(14.19) | 43.00<br>(18.33) | 60.67<br>(10.50) | 31.00<br>(7.94) |

Table 3.3. Summary of soil parameters from the natural recovery treatment in the mixedwood site (continued).

| Parameter | North Forest | North Forest Fringe | Work | Trench | Spoil | South Forest Fringe | South Forest |
|---|---|---|---|---|---|---|---|
| OM 0-10 cm (%) | 4.23 a<br>(3.35) | 5.20 a<br>(2.41) | 4.08 a<br>(1.50) | 3.55 a<br>(1.99) | 4.05 a<br>(2.39) | 4.43 a<br>(2.08) | 4.20 a<br>(1.38) |
| OM 10-20 cm (%) | 2.60<br>(1.20) | 2.53<br>(1.45) | 3.45<br>(1.70) | 3.32<br>(1.35) | 3.03<br>(2.19) | 2.48<br>(1.05) | 2.22<br>(0.43) |
| OM 20-30 cm (%) | 1.88<br>(0.62) | 1.65<br>(0.57) | 3.35<br>(2.53) | 2.90<br>(0.89) | 2.13<br>(1.12) | 1.82<br>(0.75) | 2.02<br>(0.74) |
| EC 0-10 cm (dS $m^{-1}$) | 0.12<br>(0.04) | 0.18<br>(0.10) | 0.15<br>(0.06) | 0.17<br>(0.05) | 0.20<br>(0.00) | 0.23<br>(0.05) | 0.13<br>(0.05) |
| EC 10-20 cm (dS $m^{-1}$) | 0.13<br>(0.05) | 0.15<br>(0.06) | 0.17<br>(0.05) | 0.18<br>(0.08) | 0.20<br>(0.11) | 0.18<br>(0.08) | 0.10<br>(0.00) |
| EC 20-30 cm (dS $m^{-1}$) | 0.10<br>(0.00) | 0.10<br>(0.00) | 0.15<br>(0.08) | 0.20<br>(0.00) | 0.22<br>(0.10) | 0.20<br>(0.11) | 0.10<br>(0.00) |
| pH 0-10 cm | 5.43 a<br>(0.31) | 6.57 b<br>(0.61) | 6.92 b<br>(0.75) | 7.60 bc<br>(0.41) | 7.65 bc<br>(0.21) | 7.27 b<br>(0.52) | 5.55 a<br>(0.39) |
| pH 10-20 cm | 5.73<br>(0.64) | 6.23<br>(0.58) | 6.93<br>(0.63) | 7.65<br>(0.36) | 7.28<br>(0.63) | 7.07<br>(0.68) | 5.70<br>(0.47) |
| pH 20-30 cm | 6.08<br>(0.72) | 6.22<br>(0.39) | 6.62<br>(0.89) | 7.78<br>(0.91) | 7.12<br>(1.03) | 7.17<br>(0.59) | 5.87<br>(0.39) |

Table 3.3. Summary of soil parameters from the natural recovery treatment in the mixedwood site (continued).

| Parameter | North Forest | North Forest Fringe | Work | Trench | Spoil | South Forest Fringe | South Forest |
|---|---|---|---|---|---|---|---|
| Nit 0-10 cm (mg kg-1) | 1.98<br>(0.97) | 1.62<br>(0.29) | 2.90<br>(1.15) | 2.60<br>(0.49) | 2.35<br>(0.42) | 2.12<br>(0.29) | 1.77<br>(0.48) |
| Nit 10-20 cm (mg kg$^{-1}$) | 1.77<br>(0.50) | 1.68<br>(0.38) | 2.23<br>(0.69) | 2.07<br>(0.47) | 2.15<br>(0.33) | 1.70<br>(0.45) | 1.87<br>(0.56) |
| Nit 20-30 cm (mg kg$^{-1}$) | 1.73<br>(0.28) | 1.90<br>(0.39) | 2.15<br>(0.26) | 1.98<br>(0.48) | 2.20<br>(0.45) | 1.77<br>(0.50) | 1.93<br>(0.46) |
| Phos 0-10 cm (mg kg$^{-1}$) | 32.67<br>(27.05) | 20.83<br>(13.53) | 19.17<br>(18.88) | 12.33<br>(10.67) | 10.50<br>(10.78) | 12.83<br>(15.92) | 48.67<br>(91.60) |
| Phos 10-20 cm (mg kg$^{-1}$) | 14.83<br>(19.89) | 16.17<br>(23.43) | 16.50<br>(16.06) | 8.17<br>(7.17) | 6.17<br>(8.42) | 33.83<br>(70.36) | 24.00<br>(51.94) |
| Phos 20-30 cm (mg kg$^{-1}$) | 9.50<br>(16.45) | 11.83<br>(22.17) | 9.67<br>(10.99) | 6.67<br>(6.86) | 2.83<br>(2.23) | 44.00<br>(92.83) | 6.83<br>(12.84) |
| Pot 0-10 cm (mg kg$^{-1}$) | 227.67<br>(130.47) | 171.50<br>(31.96) | 181.67<br>(47.99) | 172.67<br>(28.43) | 177.17<br>(10.69) | 204.33<br>(42.81) | 193.50<br>(94.14) |
| Pot 10-20 cm (mg kg$^{-1}$) | 178.67<br>(69.34) | 174.67<br>(81.04) | 177.33<br>(34.89) | 173.33<br>(23.50) | 194.33<br>(36.29) | 178.00<br>(55.62) | 186.17<br>(44.02) |
| Pot 20-30 cm (mg kg$^{-1}$) | 166.33<br>(59.21) | 168.00<br>(81.53) | 176.00<br>(42.73) | 169.17<br>(23.98) | 187.00<br>(43.33) | 161.33<br>(46.50) | 183.00<br>(56.65) |

Means and standard deviations are presented
Treatments that share a letter do not have statistically different means at a p-value of 0.05
Db = Bulk Density, PR = Penetration Resistance, OM = Organic Matter, EC = Electrical Conductivity, Nit = Nitrogen,
Phos = Phosphate, Pot = Potassium
N = 3

Table 3.4. Summary of vegetation parameters from the seeded and natural recovery treatment in the mixedwood site in 2002.

| Seeded Treatment | Live Cover (%) | Bare Ground (%) | Litter (%) |
|---|---|---|---|
| Work | 36.83 (13.59) a | 44.67 (23.33) a | 18.50 (10.35) a |
| Trench | 49.92 (28.18) a | 23.08 (27.52) a | 26.50 (19.82) a |
| Spoil | 39.58 (13.77) a | 33.50 (27.02) a | 25.42 (17.87) a |
| South Forest Fringe | 41.25 (8.75) a | 30.00 (25.00) a | 27.50 (17.72) a |
| South Forest | 44.58 (15.07) a | 1.67 (1.91) b | 53.75 (13.17) b |
| p-value | 0.9099 | 0.2790 | 0.0122 |
| **Natural Recovery Treatment** | **Live Cover (%)** | **Bare Ground (%)** | **Litter (%)** |
| North Forest | 19.17 (9.99) a | 4.71 (11.05) a | 75.92 (10.92) a |
| North Forest Fringe | 34.29 (14.98) a | 45.58 (23.15) b | 20.13 (18.01) b |
| Work | 44.88 (18.13) a | 43.86 (20.28) b | 11.25 (11.20) b |
| Trench | 49.58 (36.04) a | 43.71 (34.00) b | 6.71 (6.63) b |
| Spoil | 39.83 (27.23) a | 47.92 (31.12) b | 12.25 (9.16) b |
| South Forest Fringe | 38.38 (15.68) a | 41.29 (20.17) b | 20.33 (18.96) b |
| South Forest | 32.96 (16.56) a | 8.17 (16.45) a | 58.86 (15.71) a |
| p-value | 0.2777 | 0.0020 | <0.0001 |

Means and standard deviations are presented

Treatments that share a letter do not have statistically different means at a p-value of 0.05

Table 3.5. Mean cover of plant species by pipeline right-of-way zone in the seeded treatment in the mixedwood site in 2002.

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| Work | | | | | | |
| *Trifolium pratense* L. | Red Clover | I | F | NO | 15.67 | 22.24 |
| *Agropyron trachycaulum (Link) Malte* | Slender Wheatgrass | N | GSH | YES | 10.00 | 8.02 |
| *Vicia americana* Muhl | Wild Vetch | N | F | NO | 5.88 | 5.43 |
| *Lathyrus* species L. | Peavine | N | F | NO | 4.42 | 8.69 |
| *Melilotus officinalis* (L.) Lam | Yellow Sweet Clover | I | F | NO | 2.50 | 4.52 |
| *Taraxacum officinale* Weber | Dandelion | I | F | NO | 1.67 | 2.23 |
| *Equisetum arvense* L. | Common Horsetail | N | GSH | NO | 1.25 | 1.91 |
| *Schizachne purpurascens* (Torr) Swallen | Purple Oatgrass | N | G | NO | 0.88 | 1.63 |
| *Agrostis scabra* Willd | Tickle Grass | N | GSH | NO | 0.83 | 2.89 |
| *Epilobium angustifolium* L. | Fireweed | N | F | NO | 0.58 | 1.51 |
| *Festuca* species L. | Fescue | N | GSH | NO | 0.46 | 1.44 |
| *Deschampsia caespitosa* (L.) Beauv | Tufted Hairgrass | N | GSH | YES | 0.42 | 1.44 |
| *Trifolium hybridum* L. | Alsike Clover | I | F | NO | 0.17 | 0.58 |
| *Festuca saximontana* Rydb | Rocky Mountain Fescue | N | GSH | NO | 0.08 | 0.29 |
| *Trifolium* species L. | Clover | I | F | NO | 0.08 | 0.29 |
| *Melilotus* species L. | Sweet Clover | I | F | NO | 0.04 | 0.14 |
| Trench | | | | | | |
| *Trifolium pratense* L. | Red Clover | I | F | NO | 14.42 | 25.58 |
| *Agropyron trachycaulum* (Link) Malte | Slender Wheatgrass | N | GSH | YES | 10.75 | 6.94 |
| *Trifolium hybridum* L. | Alsike Clover | I | F | NO | 10.42 | 21.37 |
| *Melilotus officinalis* (L.) Lam | Yellow Sweet Clover | I | F | NO | 9.67 | 18.25 |
| *Vicia americana* Muhl | Wild Vetch | N | F | NO | 4.75 | 2.96 |

Table 3.5. Mean cover of plant species by pipeline right-of-way zone in the seeded treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| Trench | | | | | | |
| *Schizachne purpurascens* (Torr) Swallen | Purple Oatgrass | N | G | NO | 2.50 | 2.15 |
| *Mentha arvensis* L. | Wild Mint | N | F | NO | 0.83 | 1.95 |
| *Sonchus arvensis* L. | Perennial Sow Thistle | I | F | NO | 0.83 | 2.89 |
| *Taraxacum officinale* Weber | Dandelion | I | F | NO | 0.42 | 1.44 |
| *Koeleria macrantha* (Ledeb) J.A. Schultes | Junegrass | N | GSH | YES | 0.33 | 1.15 |
| *Lathyrus ochroleucus* Hook | Cream Colored Peavine | N | F | NO | 0.25 | 0.62 |
| *Agrostis scabra* Willd | Tickle Grass | N | GSH | NO | 0.21 | 0.58 |
| *Festuca ovina* L. | Sheep Fescue | I | GSH | YES | 0.17 | 0.39 |
| *Galeopsis* species L. | Nettle | N | F | NO | 0.08 | 0.29 |
| *Festuca* species L. | Fescue | N | GSH | NO | 0.04 | 0.14 |
| *Melilotus alba* Desr | White Sweet Clover | I | F | NO | 0.04 | 0.14 |
| Spoil | | | | | | |
| *Trifolium pratense* L. | Red Clover | I | F | NO | 10.67 | 12.24 |
| *Agropyron trachycaulum* (Link) Malte | Slender Wheatgrass | N | GSH | YES | 10.58 | 6.64 |
| *Trifolium repens* L. | White Clover | I | F | NO | 10.00 | 23.35 |
| *Vicia americana* Muhl | Wild Vetch | N | F | NO | 3.92 | 3.65 |
| *Lathyrus ochroleucus* Hook | Cream Colored Peavine | N | F | NO | 2.58 | 4.14 |
| *Schizachne purpurascens* (Torr) Swallen | Purple Oatgrass | N | G | NO | 1.83 | 2.52 |
| *Melilotus officinalis* (L.) Lam | Yellow Sweet Clover | I | F | NO | 1.67 | 3.50 |
| *Rosa acicularis* Lindl | Prickly Rose | N | ST | NO | 1.67 | 5.77 |
| *Festuca ovina* L. | Sheep Fescue | I | GSH | YES | 1.33 | 2.46 |
| *Poa palustris* L. | Fowl Bluegrass | N | GSH | YES | 1.08 | 1.92 |

Table 3.5. Mean cover of plant species by pipeline right-of-way zone in the seeded treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| Spoil | | | | | | |
| *Trifolium hybridum* L. | Alsike Clover | I | F | NO | 0.83 | 2.89 |
| *Equisetum arvense* L. | Common Horsetail | N | GSH | NO | 0.42 | 1.44 |
| *Lathyrus species* L. | Peavine | N | F | NO | 0.42 | 1.44 |
| *Koeleria macrantha* (Ledeb) J.A. Schultes | Junegrass | N | GSH | YES | 0.17 | 0.58 |
| *Ribes species* L. | Currant | N | ST | NO | 0.17 | 0.58 |
| *Taraxacum officinale* Weber | Dandelion | I | F | NO | 0.17 | 0.58 |
| *Melilotus* species L. | Sweet Clover | I | F | NO | 0.08 | 0.29 |
| *Deschampsia caespitosa* (L.) Beauv | Tufted Hairgrass | N | GSH | YES | 0.04 | 0.14 |
| South Forest Fringe | | | | | | |
| *Cornus canadensis* L. | Bunchberry | N | F | NO | 5.58 | 14.30 |
| *Trifolium pratense* L. | Red Clover | I | F | NO | 5.42 | 9.16 |
| *Rosa acicularis* Lindl | Prickly Rose | N | ST | NO | 4.42 | 8.66 |
| *Festuca* species L. | Fescue | N | GSH | NO | 4.21 | 9.94 |
| *Agropyron trachycaulum* (Link) Malte | Slender Wheatgrass | N | GSH | YES | 4.00 | 6.69 |
| *Calamagrostis canadensis* Michx | Bluejoint | N | GSH | NO | 2.33 | 5.79 |
| *Lathyrus ochroleucus* Hook | Cream Colored Peavine | N | F | NO | 2.00 | 4.31 |
| *Aralia nudicaulis* L. | Wild Sarsaparilla | N | F | NO | 1.67 | 5.77 |
| *Trifolium repens* L. | White Clover | I | F | NO | 1.67 | 5.77 |
| *Festuca ovina* L. | Sheep Fescue | I | GSH | YES | 1.25 | 1.76 |
| *Mertensia paniculata* (Ait) G. Don | Tall Bluebells | N | F | NO | 1.25 | 4.33 |
| *Sheperdia canadensis* (L.) Nutt | Canada Buffaloberry | N | ST | NO | 1.25 | 4.33 |
| *Vicia americana* Muhl | Wild Vetch | N | F | NO | 1.25 | 3.11 |

Table 3.5. Mean cover of plant species by pipeline right-of-way zone in the seeded treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| South Forest Fringe | | | | | | |
| *Fragaria vesca* L. | Woodland Strawberry | N | F | NO | 1.08 | 2.94 |
| *Fragaria virginiana* Duchesne | Wild Strawberry | N | F | NO | 1.08 | 2.02 |
| *Lathyrus* species L. | Peavine | N | F | NO | 0.83 | 2.89 |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | N | F | NO | 0.83 | 2.89 |
| *Epilobium angustifolium* L. | Fireweed | N | F | NO | 0.67 | 1.61 |
| *Koeleria macrantha (Ledeb) J.A. Schultes* | Junegrass | N | GSH | YES | 0.50 | 1.43 |
| *Linnaea borealis* L. | Twin Flower | N | ST | NO | 0.50 | 1.73 |
| *Equisetum arvense* L. | Common Horsetail | N | GSH | NO | 0.42 | 1.44 |
| *Poa palustris* L. | Fowl Bluegrass | N | GSH | YES | 0.42 | 1.44 |
| *Agrostis scabra* Willd | Tickle Grass | N | GSH | NO | 0.17 | 0.58 |
| *Elymus innovatus* Beal | Hairy Wild Rye | N | GSH | YES | 0.17 | 0.39 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSH | NO | 0.17 | 0.58 |
| *Vaccinium vitis-idea* L. | Bog Cranberry | N | ST | NO | 0.17 | 0.58 |
| *Carex* species L. | Sedge | N | GSH | NO | 0.04 | 0.14 |
| South Forest | | | | | | |
| *Lonicera involucrata* (Richards) Banks | Bracted Honeysuckle | N | ST | NO | 6.25 | 17.47 |
| *Cornus canadensis* L. | Bunchberry | N | F | NO | 4.42 | 3.87 |
| *Fragaria virginiana* Duchesne | Wild Strawberry | N | F | NO | 3.42 | 5.66 |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | N | F | NO | 3.08 | 4.40 |
| *Vaccinium myrtillus* | Low Bilberry | N | ST | NO | 2.33 | 6.02 |
| *Mitella nuda* L. | Bishop's Cap | N | F | NO | 2.08 | 4.98 |

Table 3.5. Mean cover of plant species by pipeline right-of-way zone in the seeded treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| South Forest | | | | | | |
| *Populus tremuloides* Michx | Trembling Aspen | N | ST | NO | 2.08 | 5.82 |
| *Aralia nudicaulis* L. | Wild Sarsaparilla | N | F | NO | 1.67 | 5.77 |
| *Arctostaphylos uva-ursi* Adans | Bearberry | N | ST | NO | 1.67 | 3.26 |
| *Lathyrus ochroleucus* Hook | Cream Colored Peavine | N | F | NO | 1.33 | 2.06 |
| *Lathyrus* species L. | Peavine | N | F | NO | 1.25 | 2.11 |
| *Rosa acicularis* Lindl | Prickly Rose | N | ST | NO | 1.25 | 3.11 |
| *Linnaea borealis* L. | Twin Flower | N | ST | NO | 1.17 | 1.95 |
| *Rubus pubescens* Raf | Dewberry | N | F | NO | 0.92 | 1.73 |
| *Vaccinium vitis-idea* L. | Bog Cranberry | N | ST | NO | 0.92 | 2.15 |
| *Symphoricarpos occidentalis* Hook | Buckbrush | N | ST | NO | 0.88 | 2.88 |
| *Calamagrostis canadensis* Michx | Bluejoint | N | GSH | NO | 0.83 | 1.27 |
| *Carex crawfordii* Fern | Crawford's Sedge | N | F | NO | 0.83 | 2.89 |
| *Ledum groenlandicum* Oeder | Common Labrador Tea | N | ST | NO | 0.83 | 1.75 |
| *Pyrola asarifolia* Michx | Common Pink Wintergreen | N | F | NO | 0.83 | 2.89 |
| *Salix* species L. | Willow | N | ST | NO | 0.83 | 1.95 |
| *Mertensia paniculata* (Ait) G. Don | Tall Bluebells | N | F | NO | 0.75 | 1.42 |
| *Viburnum edule* (Michx) Raf. | Low Bush Cranberry | N | ST | NO | 0.58 | 1.51 |
| *Galium Boreale* L. | Northern Bedstraw | N | F | NO | 0.46 | 1.44 |
| *Achillea millefolium* L. | Common Yarrow | N | F | NO | 0.42 | 1.44 |
| *Aster ciliolatus* Lindl | Lindley's Aster | N | F | NO | 0.42 | 1.44 |
| *Pyrola* species L. | Wintergreen | N | F | NO | 0.42 | 1.44 |
| *Taraxacum officinale* Weber | Dandelion | I | F | NO | 0.42 | 1.44 |
| *Equisetum arvense* L. | Common Horsetail | N | GSH | NO | 0.25 | 0.87 |

Table 3.5. Mean cover of plant species by pipeline right-of-way zone in the seeded treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| South Forest | | | | | | |
| *Ribes* species L. | Currant | N | ST | NO | 0.25 | 0.87 |
| *Galeopsis* species L. | Nettle | N | F | NO | 0.04 | 0.14 |
| *Vicia americana* Muhl | Wild Vetch | N | F | NO | 0.04 | 0.14 |

N = Native, I = Introduced, GSH = Grass, Sedge or Horsetail, ST = Shrub or Tree, F = Forb
Seeded species were those part of the seed mix applied.
N = 12, SD = standard deviation

Table 3.6. Mean cover of plant species on the pipeline right-of-way zones of the natural recovery treatment in the mixedwood site in 2002.

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| North Forest | | | | | | |
| *Cornus canadensis* L. | Bunchberry | N | F | NO | 4.67 | 5.70 |
| *Sheperdia canadensis* (L.) Nutt | Canada Buffaloberry | N | ST | NO | 1.67 | 4.58 |
| *Rosa acicularis* Lindl | Prickly Rose | N | ST | NO | 1.63 | 3.02 |
| *Populus balsamifera* L. | Balsam Poplar | N | ST | NO | 1.50 | 5.22 |
| *Fragaria virginiana* Duchesne | Wild Strawberry | N | F | NO | 1.46 | 2.39 |
| *Picea mariana* (Mill.) BSP. | Black Spruce | N | ST | NO | 1.25 | 6.12 |
| *Populus tremuloides* Michx | Trembling Aspen | N | ST | NO | 1.04 | 3.14 |
| *Viburnum edule* (Michx) Raf. | Low Bush Cranberry | N | ST | NO | 1.04 | 2.94 |
| *Aster ciliolatus* Lindl | Lindley's Aster | N | F | NO | 0.83 | 4.08 |
| *Rubus pubescens* Raf | Dewberry | N | F | NO | 0.73 | 2.15 |
| *Lathyrus* species L. | Unknown Peavine | N | F | NO | 0.67 | 1.69 |
| *Epilobium angustifolium* L. | Fireweed | N | F | NO | 0.63 | 2.24 |
| Unknown species | Unknown Species | | | NO | 0.63 | 3.06 |
| *Galium boreale* L. | Northern Bedstraw | N | F | NO | 0.58 | 1.35 |
| *Mertensia paniculata* (Ait) G. Don | Tall Bluebells | N | F | NO | 0.58 | 2.17 |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | N | F | NO | 0.58 | 1.50 |
| *Elymus innovatus* Beal | Hairy Wild Rye | N | GSH | NO | 0.56 | 1.28 |
| *Lathyrus ochroleucus* Hook | Cream Colored Peavine | N | F | NO | 0.54 | 1.56 |
| *Lonicera dioica* L. | Twining Honeysuckle | N | ST | NO | 0.46 | 1.41 |
| *Betula papyrifera (Marsh.)* | White Birch | N | ST | NO | 0.42 | 2.04 |
| *Calamagrostis canadensis* Michx | Bluejoint | N | GSH | NO | 0.35 | 0.80 |
| *Aralia nudicaulis* L. | Wild Sarsaparilla | N | F | NO | 0.33 | 1.17 |
| *Linnaea borealis* L. | Twin Flower | N | ST | NO | 0.25 | 0.61 |
| *Vicia americana* Muhl | Wild Vetch | N | F | NO | 0.17 | 0.48 |

Table 3.6. Mean cover of plant species by pipeline right-of-way zone of the natural recovery treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| North Forest | | | | | | |
| *Smilacina stellata (L.) Desf.* | Star Flowered Solomon's Seal | N | F | NO | 0.15 | 0.45 |
| *Equisetum pratense* Ehrh | Meadow Horsetail | N | GSH | NO | 0.04 | 0.20 |
| *Ribes* species L. | Currant | N | ST | NO | 0.13 | 0.61 |
| *Plantago major* L. | Common Plantain | N | F | NO | 0.08 | 0.41 |
| *Rubus idaeus* L. | Wild Red Raspberry | N | ST | NO | 0.08 | 0.41 |
| *Potentilla arguta* Pursh | White Cinquefoil | N | F | NO | 0.04 | 0.20 |
| North Forest Fringe | | | | | | |
| *Vicia americana* Muhl | Wild Vetch | N | F | NO | 6.44 | 14.18 |
| *Trifolium pratense* L. | Red Clover | I | F | NO | 5.54 | 15.39 |
| *Lathyrus ochroleucus* Hook | Cream Colored Peavine | N | F | NO | 4.71 | 7.53 |
| *Trifolium* species L. | Clover | I | F | NO | 4.42 | 14.09 |
| *Rosa acicularis* Lindl | Prickly Rose | N | ST | NO | 4.33 | 8.51 |
| *Cornus canadensis* L. | Bunchberry | N | F | NO | 3.04 | 9.86 |
| *Fragaria virginiana* Duchesne | Wild Strawberry | N | F | NO | 2.08 | 3.02 |
| *Populus tremuloides* Michx | Trembling Aspen | N | ST | NO | 1.92 | 7.19 |
| *Rubus pubescens* Raf | Dewberry | N | F | NO | 0.67 | 1.95 |
| *Erigeron philadelphicus* L. | Philadelphia Fleabane | N | F | NO | 0.63 | 3.06 |
| *Calamagrostis canadensis* Michx | Bluejoint | N | GSH | NO | 0.60 | 2.86 |
| *Trifolium hybridum* L. | Alsike Clover | I | F | NO | 0.50 | 2.45 |
| *Aster ciliolatus* Lindl | Lindley's Aster | N | F | NO | 0.46 | 1.56 |
| *Carex* species L. | Sedge | N | GSH | NO | 0.46 | 2.04 |
| *Sonchus arvensis* L. | Perennial Sow Thistle | I | F | NO | 0.46 | 2.25 |
| *Mertensia paniculata* (Ait) G. Don | Tall Bluebells | N | F | NO | 0.42 | 2.04 |

Table 3.6. Mean cover of plant species by pipeline right-of-way zone of the natural recovery treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| North Forest Fringe | | | | | | |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | N | F | NO | 0.42 | 2.04 |
| *Equisetum pratense* Ehrh | Meadow Horsetail | N | GSH | NO | 0.42 | 1.06 |
| *Aster conspicuus* Lindl. | Showy Aster | N | F | NO | 0.42 | 2.04 |
| *Elymus innovatus* Beal | Hairy Wild Rye | N | GSH | YES | 0.33 | 1.17 |
| *Geranium bicknellii* Britt | Bicknell's Geranium | N | F | NO | 0.33 | 1.43 |
| *Ribes* species L. | Currant | N | ST | NO | 0.33 | 1.63 |
| *Populus balsamifera* L. | Balsam Poplar | N | ST | NO | 0.30 | 1.28 |
| *Rubus idaeus* L. | Wild Red Raspberry | N | ST | NO | 0.29 | 1.43 |
| *Salix* species L. | Willow | N | S | NO | 0.29 | 1.08 |
| *Maianthemum canadense* Desf. | Wild Lily Of The Valley | N | F | NO | 0.21 | 1.02 |
| *Galium Boreale* L. | Northern Bedstraw | N | F | NO | 0.10 | 0.42 |
| *Carex aurea* Nutt | Golden Sedge | N | F | NO | 0.08 | 0.41 |
| *Crepis tectorum* L. | Annual Hawksbeard | I | F | NO | 0.08 | 0.41 |
| *Galium trifidum* Michx | Small Bedstraw | N | F | NO | 0.08 | 0.41 |
| *Melilotus* species L. | Sweet Clover | I | F | NO | 0.02 | 0.10 |
| *Phleum pratense* L. | Timothy | I | GSH | NO | 0.02 | 0.10 |
| Work | | | | | | |
| *Vicia americana* Muhl | Wild Vetch | N | F | NO | 14.71 | 18.71 |
| *Trifolium pratense* L. | Red Clover | I | F | NO | 14.08 | 24.47 |
| *Lathyrus ochroleucus* Hook | Cream Colored Peavine | N | F | NO | 6.79 | 10.41 |
| *Trifolium* species L. | Clover | I | F | NO | 4.13 | 10.35 |
| *Trifolium hybridum* L. | Alsike Clover | I | F | NO | 2.25 | 8.53 |
| *Mertensia paniculata* (Ait) G. Don | Tall Bluebells | N | F | NO | 1.04 | 5.10 |

Table 3.6. Mean cover of plant species by pipeline right-of-way zone of the natural recovery treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| Work | | | | | | |
| *Fragaria virginiana* Duchesne | Wild Strawberry | N | F | NO | 1.00 | 2.43 |
| *Rubus idaeus* L. | Wild Red Raspberry | N | ST | NO | 0.83 | 2.41 |
| *Phleum pratense* L. | Timothy | I | GSH | NO | 0.42 | 2.04 |
| *Rubus pubescens* Raf | Dewberry | N | F | NO | 0.42 | 2.04 |
| *Rosa acicularis* Lindl | Prickly Rose | N | ST | NO | 0.35 | 1.17 |
| *Geranium bicknellii* Britt | Bicknell's Geranium | N | F | NO | 0.33 | 1.17 |
| *Salix* species L. | Unknown Willow Species | N | S | NO | 0.21 | 1.02 |
| *Equisetum pratense* Ehrh | Meadow Horsetail | N | GSH | NO | 0.17 | 0.56 |
| *Taraxacum officinale* Weber | Dandelion | I | F | NO | 1.17 | 3.29 |
| *Aster hesperius* A. Gray | Western Willow Aster | N | F | NO | 0.08 | 0.41 |
| *Populus balsamifera* L. | Balsam Poplar | N | ST | NO | 0.08 | 0.41 |
| *Aster puniceus* L. | Purple Stemmed Aster | N | F | NO | 0.04 | 0.20 |
| *Carex aurea* Nutt | Golden Sedge | N | F | NO | 0.04 | 0.20 |
| *Equisetum arvense* L. | Common Horsetail | N | GSH | NO | 0.04 | 0.20 |
| Trench | | | | | | |
| *Trifolium pratense* L. | Red Clover | I | F | NO | 23.13 | 31.05 |
| *Trifolium hybridum* L. | Alsike Clover | I | F | NO | 14.38 | 27.71 |
| *Vicia americana* Muhl | Wild Vetch | N | F | NO | 6.71 | 15.41 |
| *Trifolium* species L. | Unknown Clover Species | I | F | NO | 3.67 | 7.33 |
| *Lathyrus ochroleucus* Hook | Cream Colored Peavine | N | F | NO | 3.42 | 6.40 |
| *Melilotus species* L. | Unknown Sweet Clover | I | F | NO | 2.46 | 6.14 |
| *Sonchus arvensis* L. | Perennial Sow Thistle | I | F | NO | 1.04 | 4.16 |
| *Plantago major* L. | Common Plantain | N | F | NO | 0.83 | 3.68 |

Table 3.6. Mean cover of plant species by pipeline right-of-way zone of the natural recovery treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| Trench | | | | | | |
| *Galium trifidum* Michx | Small Bedstraw | N | F | NO | 0.63 | 3.06 |
| *Phleum pratense* L. | Timothy | I | GSH | NO | 0.33 | 1.63 |
| *Taraxacum officinale* Weber | Dandelion | I | F | NO | 0.21 | 1.02 |
| *Carex crawfordii* Fern | Crawford's Sedge | N | F | NO | 0.17 | 0.82 |
| *Potentilla arguta* Pursh | White Cinquefoil | N | F | NO | 0.17 | 0.82 |
| *Calamagrostis canadensis* Michx | Bluejoint | N | GSH | NO | 0.13 | 0.61 |
| *Lathyrus* species L. | Unknown Peavine | N | F | NO | 0.13 | 0.61 |
| *carex* species L. | Unknown Sedge Species | N | GSH | NO | 0.13 | 0.61 |
| *Equisetum pratense* Ehrh | Meadow Horsetail | N | GSH | NO | 0.13 | 0.45 |
| *Rubus idaeus* L. | Wild Red Raspberry | N | ST | NO | 0.13 | 0.61 |
| *Aster puniceus* L. | Purple Stemmed Aster | N | F | NO | 0.08 | 0.41 |
| *Fragaria vesca* L. | Woodland Strawberry | N | F | NO | 0.08 | 0.28 |
| *Galeopsis* species L. | Unknown Nettle Species | N | F | NO | 0.08 | 0.41 |
| *Viola* species L. | Unknown Violet Species | N | F | NO | 0.08 | 0.41 |
| *Epilobium angustifolium* L. | Fireweed | N | F | NO | 0.06 | 0.22 |
| *Populus balsamifera* L. | Balsam Poplar | N | ST | NO | 0.02 | 0.10 |
| Spoil | | | | | | |
| *Trifolium hybridum* L. | Alsike Clover | I | F | NO | 18.54 | 29.65 |
| *Trifolium pratense* L. | Red Clover | I | F | NO | 10.33 | 22.95 |
| *Vicia americana* Muhl | Wild Vetch | N | F | NO | 4.79 | 7.94 |
| *Lathyrus ochroleucus* Hook | Cream Colored Peavine | N | F | NO | 3.00 | 5.80 |
| *Trifolium* species L. | Unknown Clover Species | I | F | NO | 2.83 | 6.25 |
| *Salix* species L. | Unknown Willow Species | N | S | NO | 0.69 | 1.90 |

Table 3.6. Mean cover of plant species by pipeline right-of-way zone of the natural recovery treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| Spoil | | | | | | |
| *Taraxacum officinale* Weber | Dandelion | I | F | NO | 0.63 | 2.12 |
| *Lathyrus* species L. | Unknown Peavine | N | F | NO | 0.42 | 2.04 |
| *Fragaria virginiana* Duchesne | Wild Strawberry | N | F | NO | 0.27 | 0.85 |
| *Potentilla arguta* Pursh | White Cinquefoil | N | F | NO | 0.21 | 0.83 |
| *Sonchus arvensis* L. | Perennial Sow Thistle | I | F | NO | 0.21 | 1.02 |
| Unknown species | Unknown Species | | | NO | 0.21 | 1.02 |
| *Trifolium repens* L. | White Clover | I | F | NO | 0.17 | 0.82 |
| *Phleum pratense* L. | Timothy | I | GSH | NO | 0.17 | 0.82 |
| *Carex aurea* Nutt | Golden Sedge | N | F | NO | 0.13 | 0.45 |
| *Carex crawfordii* Fern | Crawford's Sedge | N | F | NO | 0.13 | 0.61 |
| *Geranium bicknellii* Britt | Bicknell's Geranium | N | F | NO | 0.13 | 0.61 |
| *Equisetum pratense* Ehrh | Meadow Horsetail | N | GSH | NO | 0.08 | 0.28 |
| *Equisetum* sylvaticum L. | Woodland Horsetail | N | GSH | NO | 0.08 | 0.41 |
| *Plantago major* L. | Common Plantain | N | F | NO | 0.08 | 0.41 |
| *Equisetum arvense* L. | Common Horsetail | N | GSH | NO | 0.04 | 0.20 |
| *Mertensia paniculata* (Ait) G. Don | Tall Bluebells | N | F | NO | 0.04 | 0.20 |
| *Agrostis scabra* Willd | Tickle Grass | N | GSH | NO | 0.02 | 0.10 |
| *Galeopsis tetrahit* L. | Hemp Nettle | N | F | NO | 0.02 | 0.10 |
| *Pyrola* species L. | Unknown Wintergreen | N | F | NO | 0.02 | 0.10 |
| South Forest Fringe | | | | | | |
| *Trifolium pratense* L. | Red Clover | I | F | NO | 8.00 | 15.11 |
| *Lathyrus ochroleucus* Hook | Cream Colored Peavine | N | F | NO | 4.38 | 8.16 |
| *Trifolium hybridum* L. | Alsike Clover | I | F | NO | 4.17 | 9.52 |

Table 3.6. Mean cover of plant species by pipeline right-of-way zone of the natural recovery treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| South Forest Fringe | | | | | | |
| *Elymus innovatus* Beal | Hairy Wild Rye | N | GSH | NO | 3.17 | 10.31 |
| *Rubus pubescens* Raf | Dewberry | N | F | NO | 2.92 | 11.51 |
| *Fragaria virginiana* Duchesne | Wild Strawberry | N | F | NO | 2.08 | 4.77 |
| *Trifolium* species L. | Unknown Clover Species | I | F | NO | 1.79 | 5.36 |
| *Aralia nudicaulis* L. | Wild Sarsaparilla | N | F | NO | 1.25 | 6.12 |
| *Achillea millefolium* L. | Common Yarrow | N | F | NO | 0.29 | 1.08 |
| *Calamagrostis canadensis* Michx | Bluejoint | N | GSH | NO | 0.96 | 3.11 |
| *Plantago major* L. | Common Plantain | N | F | NO | 0.83 | 4.08 |
| *Poa palustris* L. | Fowl Bluegrass | N | GSH | YES | 0.71 | 2.61 |
| *Taraxacum officinale* Weber | Dandelion | I | F | NO | 0.71 | 1.88 |
| *Cornus canadensis* L. | Bunchberry | N | F | NO | 0.63 | 2.24 |
| *Mertensia paniculata* (Ait) G. Don | Tall Bluebells | N | F | NO | 0.60 | 2.20 |
| *Aster* species L. | Unknown Aster Species | N | F | NO | 0.58 | 2.86 |
| *Phleum pratense* L. | Timothy | I | GSH | NO | 0.50 | 2.45 |
| *Populus balsamifera* L. | Balsam Poplar | N | ST | NO | 0.50 | 2.45 |
| *Viola* species L. | Unknown Violet Species | N | F | NO | 0.50 | 2.45 |
| *Aster ciliolatus* Lindl | Lindley's Aster | N | F | NO | 0.42 | 1.41 |
| *Potentilla arguta* Pursh | White Cinquefoil | N | F | NO | 0.42 | 2.04 |
| *Agrostis scabra* Willd | Tickle Grass | N | GSH | NO | 0.35 | 1.63 |
| *Rubus idaeus* L. | Wild Red Raspberry | N | ST | NO | 0.35 | 0.52 |
| *Equisetum pratense* Ehrh | Meadow Horsetail | N | GSH | NO | 0.25 | 0.90 |
| *Rosa acicularis* Lindl | Prickly Rose | N | ST | NO | 0.17 | 0.82 |
| *Populus tremuloides* Michx | Trembling Aspen | N | ST | NO | 0.13 | 0.61 |
| *Aster puniceus* L. | Purple Stemmed Aster | N | F | NO | 0.08 | 0.41 |

Table 3.6. Mean cover of plant species by pipeline right-of-way zone of the natural recovery treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| South Forest | | | | | | |
| *Mentha arvensis* L. | Wild Mint | N | F | NO | 0.08 | 0.41 |
| *Aster laevis* L. | Smooth Aster | N | F | NO | 0.04 | 0.20 |
| *Carex* species L. | Unknown Sedge Species | N | GSH | NO | 0.04 | 0.20 |
| *Equisetum arvense* L. | Common Horsetail | N | GSH | NO | 0.04 | 0.20 |
| *Festuca* species L. | Unknown Fescue Species | N | GSH | NO | 0.02 | 0.10 |
| *Lonicera involucrata* (Richards) Banks | Bracted Honeysuckle | N | ST | NO | 0.02 | 0.10 |
| *Cornus canadensis* L. | Bunchberry | N | F | NO | 8.54 | 7.22 |
| *Lathyrus ochroleucus* Hook | Cream Colored Peavine | N | F | NO | 2.38 | 5.00 |
| *Aralia nudicaulis* L. | Wild Sarsaparilla | N | F | NO | 2.17 | 4.36 |
| *Fragaria virginiana* Duchesne | Wild Strawberry | N | F | NO | 2.08 | 3.03 |
| *Rosa acicularis* Lindl | Prickly Rose | N | ST | NO | 1.50 | 4.24 |
| *Rubus pubescens* Raf | Dewberry | N | F | NO | 1.33 | 3.29 |
| *Mitella nuda* L. | Bishop's Cap | N | F | NO | 1.31 | 1.98 |
| *Alnus crispa* (Ait) Pursh | Green Alder | N | ST | NO | 1.25 | 6.12 |
| *Populus tremuloides* Michx | Trembling Aspen | N | ST | NO | 1.08 | 4.16 |
| *Calamagrostis canadensis Michx* | Bluejoint | N | GSH | NO | 0.96 | 2.27 |
| *Lonicera involucrata* (Richards) Banks | Bracted Honeysuckle | N | ST | NO | 0.94 | 3.11 |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | N | F | NO | 0.92 | 1.89 |
| *Aster ciliolatus* Lindl | Lindley's Aster | N | F | NO | 0.88 | 2.33 |
| *Rubus idaeus* L. | Wild Red Raspberry | N | ST | NO | 0.88 | 3.25 |
| *Elymus innovatus* Beal | Hairy Wild Rye | N | GSH | NO | 0.85 | 2.82 |
| *Linnaea borealis* L. | Twin Flower | N | ST | NO | 0.67 | 1.52 |
| *Mertensia paniculata* (Ait) G. Don | Tall Bluebells | N | F | NO | 0.63 | 2.12 |

Table 3.6. Mean cover of plant species by pipeline right-of-way zone of the natural recovery treatment in the mixedwood site in 2002 (continued).

| Scientific Name | Common Name | Type | | Seeded | Cover (%) | SD |
|---|---|---|---|---|---|---|
| South Forest | | | | | | |
| *Populus balsamifera* L. | Balsam Poplar | N | ST | NO | 0.63 | 3.06 |
| *Plantago major* L. | Common Plantain | N | F | NO | 0.50 | 1.72 |
| *Smilacina stellata* (L.) Desf. | Star Flowered Solomon's Seal | N | F | NO | 0.46 | 1.61 |
| *Aster puniceus* L. | Purple Stemmed Aster | N | F | NO | 0.42 | 2.04 |
| *Fragaria vesca* L. | Woodland Strawberry | N | F | NO | 0.42 | 1.41 |
| *Pyrola Asarifolia* Michx | Common Pink Wintergreen | N | F | NO | 0.42 | 1.14 |
| *Maianthemum canadense* Desf. | Wild Lily Of The Valley | N | F | NO | 0.38 | 0.92 |
| *Viburnum edule* (Michx) Raf. | Low Bush Cranberry | N | ST | NO | 0.33 | 1.02 |
| *Potentilla arguta* Pursh | White Cinquefoil | N | F | NO | 0.17 | 0.56 |
| *Vaccinium vitis-idea* L. | Bog Cranberry | N | ST | NO | 0.13 | 0.61 |
| *Galium Boreale* L. | Northern Bedstraw | N | F | NO | 0.08 | 0.24 |
| *Pyrola* species L. | Unknown Wintergreen | N | F | NO | 0.08 | 0.41 |
| *Equisetum pratense* Ehrh | Meadow Horsetail | N | GSH | NO | 0.04 | 0.20 |
| *Stipa* species L. | Needle Grass | N | G | NO | 0.04 | 0.20 |

N = Native, I = Introduced, GSH = Grass, Sedge or Horsetail, ST = Shrub or Tree, F = Forb,
Seeded species were those part of the seed mix applied.
N = 12, SD = standard deviation

Table 3.7. Summary of key ground cover characteristics from the topographic low and high treatments in the peatland site in 2002.

| Topographic Low | Live Cover (%) | | Bare Ground (%) | | Litter (%) | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| East Forest | 60.25 | 32.84 | 3.33 | 11.05 | 35.58 | 30.79 |
| East Forest Fringe | 52.75 | 26.32 | 11.25 | 17.34 | 35.17 | 16.93 |
| Work | 57.42 | 26.45 | 26.08 | 25.18 | 16.08 | 9.22 |
| Trench | 22.50 | 15.89 | 69.67 | 19.41 | 7.83 | 6.10 |
| Spoil | 61.33 | 31.44 | 10.42 | 15.73 | 28.25 | 25.99 |
| West Forest Fringe | 32.17 | 33.39 | 50.75 | 27.78 | 17.08 | 14.55 |
| West Forest | 78.58 | 28.32 | 5.00 | 17.32 | 6.42 | 17.30 |
| Topographic High | | | | | | |
| East Forest | 83.92 | 18.22 | 0.00 | 0.00 | 16.08 | 18.22 |
| East Forest Fringe | 15.25 | 21.08 | 70.83 | 22.14 | 3.08 | 4.48 |
| Work | 18.67 | 14.06 | 63.08 | 23.11 | 8.25 | 16.42 |
| Trench | 8.67 | 12.77 | 89.50 | 9.11 | 4.33 | 4.19 |
| Spoil | 14.67 | 12.20 | 66.67 | 13.03 | 17.83 | 9.45 |
| West Forest Fringe | 20.17 | 17.71 | 53.08 | 17.38 | 26.75 | 9.33 |
| West Forest | 93.58 | 13.88 | 0.00 | 0.00 | 6.42 | 13.88 |

SD = standard deviation

Table 3.8. Mean cover of plant species by pipeline right-of-way zones of the topographic low treatment in the peatland site in 2002.

| Scientific Name | Common Name | Type | | Cover (%) | SD |
|---|---|---|---|---|---|
| East Forest | | | | | |
| Moss species | Unknown Moss Species | N | | 42.08 | 34.34 |
| *Betula glandulosa* Michx | Bog Birch | N | ST | 5.67 | 7.84 |
| *Ledum groenlandicum* Oeder | Common Labrador Tea | N | ST | 5.50 | 11.29 |
| *Rubus chamaemorus* L. | Cloudberry | N | F | 5.25 | 7.15 |
| *Calamagrostis canadensis* Michx | Bluejoint/Marsh Reed Grass | N | GSFH | 4.50 | 7.55 |
| *Salix lutea* Nutt. | Yellow Willow | N | ST | 2.92 | 7.22 |
| *Carex* species L. | Unknown Sedge Species | N | GSFH | 2.75 | 3.17 |
| *Carex aquatilus* Wahlenb. | Water Sedge | N | GSFH | 1.83 | 4.30 |
| *Smilacina stellata* (L.) Desf. | Star Flowered Solomon's Seal | N | F | 1.50 | 4.34 |
| *Rubus idaeus* L. | Wild Red Raspberry | N | ST | 1.25 | 4.33 |
| *Salix pedicellaris* Pursh | Bog Willow | N | ST | 1.00 | 1.95 |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | N | F | 0.83 | 2.89 |
| *Ribes* species L. | Unknown Currant | N | ST | 0.83 | 2.89 |
| *Vaccinium vitis-idaea* L. | Bog Cranberry | N | ST | 0.83 | 1.75 |
| *Equisetum fluviatile* L. | Swamp Horsetail | N | GSFH | 0.42 | 1.44 |
| *Potentilla norvegica* L. | Rough Cinquefoil | N | F | 0.42 | 1.00 |
| *Andromeda polifolia* L. | Bog Rosemary | N | F | 0.33 | 1.16 |
| *Equisetum hyemale* L. | Common Scouring Rush | N | GSFH | 0.17 | 0.39 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSFH | 0.17 | 0.39 |
| *Glyceria striata* (Lam.) A.S. Hitchc. | Fowl Manna Grass | N | GSFH | 0.17 | 0.58 |
| Fern species | Unknown Fern Species | N | GSFH | 0.08 | 0.29 |
| *Picea mariana* (Mill.) BSP. | Black Spruce | N | ST | 0.08 | 0.29 |
| East Forest Fringe | | | | | |
| Moss species | Unknown Moss Species | N | | 30.25 | 22.72 |

Table 3.8. Mean cover of plant species by pipeline right-of-way zones of the topographic low treatment in the peatland site in 2002 (continued).

| Scientific Name | Common Name | Type | | Cover (%) | SD |
|---|---|---|---|---|---|
| East Forest Fringe | | | | | |
| *Calamagrostis canadensis Michx* | Bluejoint/Marsh Reed Grass | N | GSFH | 19.75 | 25.04 |
| *Salix lutea* Nutt. | Yellow Willow | N | ST | 8.08 | 13.37 |
| *Carex aquatilus* Wahlenb. | Water Sedge | N | GSFH | 5.08 | 10.66 |
| *Carex* species L. | Unknown Sedge Species | N | GSFH | 4.00 | 6.22 |
| *Ledum groenlandicum* Oeder | Common Labrador Tea | N | ST | 3.33 | 7.79 |
| *Potentilla norvegica* L. | Rough Cinquefoil | N | F | 3.25 | 5.33 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSFH | 2.75 | 8.63 |
| *Rubus chamaemorus* L. | Cloudberry | N | F | 2.08 | 4.32 |
| *Salix pedicellaris* Pursh | Bog Willow | N | ST | 1.67 | 3.89 |
| *Smilacina stellata* (L.) Desf. | Star Flowered Solomon's Seal | N | F | 1.67 | 3.99 |
| *Betula glandulosa* Michx | Bog Birch | N | ST | 0.83 | 1.99 |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | N | F | 0.83 | 2.33 |
| *Rubus pubescens* Raf | Dewberry | N | F | 0.83 | 2.33 |
| *Cornus canadensis* L. | Bunchberry | N | F | 0.42 | 1.44 |
| *Epilobium angustifolium* L. | Fireweed | N | F | 0.42 | 1.44 |
| *Vaccinium vitis-idaea* L. | Bog Cranberry | N | ST | 0.42 | 1.44 |
| *Equisetum hyemale* L. | Common Scouring Rush | N | GSFH | 0.25 | 0.45 |
| *Agrostis scabra* Willd | Tickle Grass | N | GSFH | 0.25 | 0.62 |
| Fern species | Unknown Fern Species | N | GSFH | 0.08 | 0.29 |
| *Salix petiolaris* J.E. Smith | Basket Willow | N | ST | 0.08 | 0.29 |
| *Andromeda polifolia* L. | Bog Rosemary | N | F | 0.08 | 0.29 |

Table 3.8. Mean cover of plant species by pipeline right-of-way zones of the topographic low treatment in the peatland site in 2002 (continued).

| Scientific Name | Common Name | Type | | Cover (%) | SD |
|---|---|---|---|---|---|
| Work | | | | | |
| Moss species | Unknown Moss Species | N | | 31.00 | 33.51 |
| *Calamagrostis canadensis* Michx | Bluejoint/Marsh Reed Grass | N | GSFH | 14.17 | 22.04 |
| *Carex aquatilus* Wahlenb. | Water Sedge | N | GSFH | 10.08 | 11.15 |
| *Equisetum scirpoides* Michx | Dwarf Scouring Rush | N | GSFH | 2.50 | 8.66 |
| *Carex* species L. | Unknown Sedge Species | N | GSFH | 2.00 | 2.80 |
| *Equisetum hyemale* L. | Common Scouring Rush | N | GSFH | 1.92 | 2.02 |
| *Agrostis scabra* Willd | Tickle Grass | N | GSFH | 1.42 | 2.91 |
| *Glyceria striata* (Lam.) A.S. Hitchc. | Fowl Manna Grass | N | GSFH | 1.00 | 1.95 |
| *Epilobium palustre* L. | Marsh Willow Herb | N | F | 0.83 | 1.95 |
| *Equisetum arvense* L. | Common Horsetail | N | GSFH | 0.75 | 1.60 |
| *Potentilla norvegica* L. | Rough Cinquefoil | N | F | 0.42 | 1.44 |
| *Epilobium angustifolium* L. | Fireweed | N | F | 0.25 | 0.87 |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | N | F | 0.17 | 0.58 |
| *Salix lutea* Nutt. | Yellow Willow | N | ST | 0.07 | 0.58 |
| Trench | | | | | |
| Moss species | Unknown Moss Species | N | | 8.25 | 15.02 |
| *Agrostis scabra* Willd | Tickle Grass | N | GSFH | 5.58 | 5.87 |
| *Carex aquatilus* Wahlenb. | Water Sedge | N | GSFH | 4.08 | 4.38 |
| *Equisetum hyemale* L. | Common Scouring Rush | N | GSFH | 2.33 | 2.54 |
| *Equisetum arvense* L. | Common Horsetail | N | GSFH | 1.75 | 3.14 |
| *Carex* species L. | Unknown Sedge Species | N | GSFH | 0.83 | 1.75 |
| *Glyceria striata* (Lam.) A.S. Hitchc. | Fowl Manna Grass | N | GSFH | 0.83 | 2.89 |

Table 3.8. Mean cover of plant species by pipeline right-of-way zones of the topographic low treatment in the peatland site in 2002 (continued).

| Scientific Name | Common Name | Type | | Cover (%) | SD |
|---|---|---|---|---|---|
| Trench | | | | | |
| *Epilobium palustre* L. | Marsh Willow Herb | N | F | 0.67 | 1.50 |
| *Equisetum scirpoides* Michx | Dwarf Scouring Rush | N | GSFH | 0.50 | 1.45 |
| *Potentilla norvegica* L. | Rough Cinquefoil | N | F | 0.33 | 1.16 |
| *Carex crawfordii* Fern. | Crawford's Sedge | N | GSFH | 0.25 | 0.87 |
| *Calamagrostis canadensis* Michx | Bluejoint/Marsh Reed Grass | N | GSFH | 0.17 | 0.58 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSFH | 0.17 | 0.58 |
| *Kalmia polifolia* Wang. | Northern Bog Laurel | N | F | 0.08 | 0.29 |
| *Salix lutea* Nutt. | Yellow Willow | N | ST | 0.08 | 0.29 |
| Spoil | | | | | |
| Moss species | Unknown Moss Species | N | | 33.92 | 36.71 |
| *Carex* species L. | Unknown Sedge Species | N | GSFH | 10.25 | 12.48 |
| *Glyceria striata* (Lam.) A.S. Hitchc. | Fowl Manna Grass | N | GSFH | 7.50 | 16.45 |
| *Calamagrostis canadensis* Michx | Bluejoint/Marsh Reed Grass | N | GSFH | 7.08 | 10.99 |
| *Agrostis scabra* Willd | Tickle Grass | N | GSFH | 5.17 | 8.17 |
| *Carex aquatilus* Wahlenb. | Water Sedge | N | GSFH | 4.58 | 4.40 |
| *Calla palustris* L. | Water Arum | N | F | 3.75 | 12.99 |
| *Equisetum hyemale* L. | Common Scouring Rush | N | GSFH | 2.42 | 3.26 |
| *Potentilla norvegica* L. | Rough Cinquefoil | N | F | 1.67 | 3.89 |
| *Epilobium angustifolium* L. | Fireweed | N | F | 1.25 | 4.33 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSFH | 0.50 | 0.80 |
| *Salix pedicellaris* Pursh | Bog Willow | N | ST | 0.50 | 1.73 |

Table 3.8. Mean cover of plant species by pipeline right-of-way zones of the topographic low treatment in the peatland site in 2002 (continued).

| Scientific Name | Common Name | Type | | Cover (%) | SD |
|---|---|---|---|---|---|
| Spoil | | | | | |
| *Eriophorum angustifolium* Honck. | Tall Cotton Grass | N | GSFH | 0.25 | 0.87 |
| *Smilacina stellata* (L.) Desf. | Star Flowered Solomon's Seal | N | F | 0.25 | 0.87 |
| *Ledum groenlandicum* Oeder | Common Labrador Tea | N | ST | 0.25 | 0.87 |
| West Forest Fringe | | | | | |
| Moss species | Unknown Moss Species | N | | 18.83 | 29.32 |
| *Rubus chamaemorus* L. | Cloudberry | N | F | 2.67 | 4.79 |
| *Calamagrostis canadensis* Michx | Bluejoint/Marsh Reed Grass | N | GSFH | 1.83 | 3.33 |
| *Carex* species L. | Unknown Sedge Species | N | GSFH | 1.83 | 3.83 |
| *Carex aquatilus* Wahlenb. | Water Sedge | N | GSFH | 1.33 | 3.09 |
| *Aster pansus* Blake | Tufted White Aster | N | F | 1.25 | 4.33 |
| *Smilacina stellata* (L.) Desf. | Star Flowered Solomon's Seal | N | F | 1.17 | 2.92 |
| *Rubus pubescens* Raf | Dewberry | N | F | 1.08 | 2.61 |
| *Equisetum hyemale* L. | Common Scouring Rush | N | GSFH | 1.00 | 1.28 |
| *Betula glandulosa* Michx | Bog Birch | N | ST | 0.83 | 1.85 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSFH | 0.75 | 1.77 |
| *Potentilla norvegica* L. | Rough Cinquefoil | N | F | 0.58 | 1.38 |
| *Equisetum arvense* L. | Common Horsetail | N | GSFH | 0.50 | 1.45 |
| *Rubus idaeus* L. | Wild Red Raspberry | N | ST | 0.42 | 1.44 |
| *Carex crawfordii* Fern. | Crawford's Sedge | N | GSFH | 0.33 | 0.89 |
| *Festuca* species L. | Unknown Fescue Species | I | GSFH | 0.33 | 0.89 |
| *Salix lutea* Nutt. | Yellow Willow | N | ST | 0.33 | 0.89 |

Table 3.8. Mean cover of plant species by pipeline right-of-way zones of the topographic low treatment in the peatland site in 2002 (continued).

| Scientific Name | Common Name | Type | | Cover (%) | SD |
|---|---|---|---|---|---|
| West Forest Fringe | | | | | |
| *Epilobium angustifolium* L. | Fireweed | N | F | 0.25 | 0.87 |
| *Ledum groenlandicum* Oeder | Common Labrador Tea | N | ST | 0.17 | 0.58 |
| *Agrostis scabra* Willd | Tickle Grass | N | GSFH | 0.08 | 0.29 |
| *Kalmia polifolia* Wang. | Northern Bog Laurel | N | F | 0.08 | 0.29 |
| *Salix pedicellaris* Pursh | Bog Willow | N | ST | 0.08 | 0.29 |
| West Forest | | | | | |
| Moss Species | Unknown Moss Species | N | | 74.00 | 33.70 |
| *Ledum groenlandicum* Oeder | Common Labrador Tea | N | ST | 15.08 | 22.17 |
| *Rubus chamaemorus* L. | Cloudberry | N | F | 7.92 | 10.08 |
| *Betula glandulosa* Michx | Bog Birch | N | ST | 7.33 | 7.00 |
| *Salix lutea* Nutt. | Yellow Willow | N | ST | 4.50 | 5.87 |
| *Alnus crispa* (Ait.) Pursh | Green Alder | N | ST | 3.75 | 12.99 |
| *Calla palustris* L. | Water Arum | N | F | 3.33 | 11.55 |
| *Carex* species L. | Unknown Sedge Species | N | GSFH | 1.75 | 3.05 |
| *Rubus pubescens* Raf | Dewberry | N | F | 1.67 | 4.44 |
| *Andromeda polifolia* L. | Bog Rosemary | N | F | 1.42 | 4.30 |
| *Calamagrostis canadensis* Michx | Bluejoint/Marsh Reed Grass | N | GSFH | 1.17 | 2.21 |
| *Carex aquatilus* Wahlenb. | Water Sedge | N | GSFH | 1.08 | 2.15 |
| *Kalmia polifolia* Wang. | Northern Bog Laurel | N | F | 0.92 | 2.39 |
| *Smilacina stellata* (L.) Desf. | Star Flowered Solomon's Seal | N | F | 0.83 | 1.99 |
| *Vaccinium vitis-idaea* L. | Bog Cranberry | N | ST | 0.42 | 1.44 |

Table 3.8. Mean cover of plant species by pipeline right-of-way zones of the topographic low treatment in the peatland site in 2002 (continued).

| Scientific Name | Common Name | Type | | Cover (%) | SD |
|---|---|---|---|---|---|
| West Forest | | | | | |
| *Potentilla norvegica* L. | Rough Cinquefoil | N | F | 0.33 | 1.16 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSFH | 0.17 | 0.39 |
| *Equisetum hyemale* L. | Common Scouring Rush | N | GSFH | 0.08 | 0.29 |

N = native, I = introduced, GSFH = grass, sedge, fern or horsetail, ST = shrub or tree, F = forb

N = 84, SD = standard deviation

Table 3.9. Mean cover of plant species by pipeline right-of-way zone of the topographic high treatment in the peatland site in 2002.

| Scientific Name | Common Name | Type | | Cover (%) | SD |
|---|---|---|---|---|---|
| East Forest | | | | | |
| Moss species | Unknown Moss Species | N | | 73.25 | 28.55 |
| *Ledum groenlandicum* Oeder | Common Labrador Tea | N | ST | 18.17 | 23.59 |
| *Vaccinium myrtilloides* Michx | Blueberry | N | ST | 7.17 | 10.27 |
| *Vaccinium vitis-idaea* L. | Bog Cranberry | N | ST | 5.92 | 14.02 |
| *Salix lutea* Nutt. | Yellow Willow | N | ST | 4.67 | 15.85 |
| *Betula pumila* L. | Dwarf Birch | N | ST | 4.08 | 12.94 |
| *Populus balsamifera* L. | Balsam Poplar | N | ST | 3.33 | 11.55 |
| *Lonicera involucrata* (Richards.) Banks | Bracted Honeysuckle | N | ST | 1.67 | 5.77 |
| *Cornus canadensis* L. | Bunchberry | N | F | 0.58 | 1.00 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSFH | 0.50 | 1.45 |
| *Gaultheria hispidula* (L.) Bigel. | Creeping Snowberry | N | ST | 0.42 | 1.44 |
| *Kalmia polifolia* Wang. | Northern Bog Laurel | N | F | 0.42 | 1.44 |
| *Andromeda polifolia* L. | Bog Rosemary | N | F | 0.17 | 0.58 |
| *Elymus innovatus* Beal | Hairy Wild Rye | N | GSFH | 0.17 | 0.58 |
| *Linnaea borealis* L. | Twin-flower | N | ST | 0.17 | 0.58 |
| *Betula glandulosa* Michx | Bog Birch | N | ST | 0.08 | 0.29 |
| *Vaccinium uliginosum* L. | Bog Bilberry | N | ST | 0.08 | 0.29 |
| East Forest Fringe | | | | | |
| *Vaccinium myrtilloides* Michx | Blueberry | N | ST | 8.58 | 18.37 |
| *Ledum groenlandicum* Oeder | Common Labrador Tea | N | ST | 1.92 | 3.87 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSFH | 1.50 | 4.28 |
| *Betula pumila* L. | Dwarf Birch | N | ST | 1.25 | 4.33 |

Table 3.9. Mean cover of plant species by pipeline right-of-way zone of the topographic high treatment in the peatland site in 2002 (continued).

| Scientific Name | Common Name | Type | | Cover (%) | SD |
|---|---|---|---|---|---|
| East Forest Fringe | | | | | |
| *Cornus canadensis* L. | Bunchberry | N | F | 1.08 | 1.73 |
| *Calamagrostis canadensis* Michx | Bluejoint/Marsh Reed Grass | N | GSFH | 1.00 | 2.89 |
| *Mertensia paniculata* (Ait) G. Don | Tall Bluebells | N | F | 0.50 | 1.45 |
| *Rubus chamaemorus* L. | Cloudberry | N | F | 0.42 | 1.44 |
| *Salix maccalliana* Rowlee | Maccall's Willow | N | ST | 0.42 | 1.44 |
| *Equisetum arvense* L. | Common Horsetail | N | GSFH | 0.25 | 0.87 |
| *Elymus innovatus* Beal | Hairy Wild Rye | N | GSFH | 0.17 | 0.58 |
| *Calamagrostis inexpansa* A. Gray | Northern Reed Grass | N | GSFH | 0.08 | 0.29 |
| *Carex* species L. | Unknown Sedge Species | N | GSFH | 0.08 | 0.29 |
| *Vaccinium vitis-idaea* L. | Bog Cranberry | N | ST | 0.08 | 0.29 |
| Work | | | | | |
| *Carex* species L. | Unknown Sedge Species | N | GSFH | 2.58 | 3.37 |
| *Equisetum arvense* L. | Common Horsetail | N | GSFH | 2.08 | 4.98 |
| *Vaccinium myrtilloides* Michx | Blueberry | N | ST | 1.58 | 2.07 |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | N | F | 1.08 | 2.94 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSFH | 1.00 | 2.89 |
| *Elymus innovatus* Beal | Hairy Wild Rye | N | GSFH | 0.83 | 2.89 |
| *Calamagrostis canadensis* Michx | Bluejoint/Marsh Reed Grass | N | GSFH | 0.83 | 1.95 |
| *Trifolium repens* L. | White Clover | I | F | 0.83 | 2.89 |
| *Festuca* species L. | Unknown Fescue Species | I | GSFH | 0.67 | 2.31 |
| *Rosa acicularis* Lindl | Prickly Rose | N | ST | 0.50 | 1.45 |

Table 3.9. Mean cover of plant species by pipeline right-of-way zone of the topographic high treatment in the peatland site in 2002 (continued).

| Scientific Name | Common Name | Type | | Cover (%) | SD |
|---|---|---|---|---|---|
| East Forest Fringe | | | | | |
| *Cornus canadensis* L. | Bunchberry | N | F | 0.42 | 1.44 |
| *Rubus pubescens* Raf | Dewberry | N | F | 0.42 | 1.44 |
| Trench | | | | | |
| *Festuca ovina* L. | Sheep Fescue | I | GSFH | 0.08 | 0.29 |
| *Linnaea borealis* L. | Twin-flower | N | ST | 0.08 | 0.29 |
| *Agrostis scabra* Willd | Tickle Grass | N | GSFH | 0.25 | 0.87 |
| *Epilobium angustifolium* L. | Fireweed | N | F | 4.25 | 10.15 |
| *Equisetum scirpoides* Michx | Dwarf Scouring Rush | N | GSFH | 0.58 | 1.17 |
| *Festuca* species L. | Unknown Fescue Species | I | GSFH | 0.58 | 1.51 |
| *Agrostis scabra* Willd | Tickle Grass | N | GSFH | 0.33 | 0.65 |
| *Carex* species L. | Unknown Sedge Species | N | GSFH | 0.17 | 0.39 |
| *Galeopsis tetrahit* L. | Hemp Nettle | N | F | 0.17 | 0.58 |
| *Calamagrostis canadensis* Michx | Bluejoint/Marsh Reed Grass | N | GSFH | 0.08 | 0.29 |
| *Cornus canadensis* L. | Bunchberry | N | F | 0.08 | 0.29 |
| *Elymus innovatus* Beal | Hairy Wild Rye | N | GSFH | 0.08 | 0.29 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSFH | 0.08 | 0.29 |
| Spoil | | | | | |
| *Salix lutea* Nutt. | Yellow Willow | N | ST | 3.33 | 11.55 |
| *Carex* species L. | Unknown Sedge Species | N | GSFH | 3.00 | 7.08 |
| Moss species | Unknown Moss Species | N | | 2.67 | 4.46 |
| *Epilobium angustifolium* L. | Fireweed | N | F | 2.33 | 6.02 |

Table 3.9. Mean cover of plant species by pipeline right-of-way zone of the topographic high treatment in the peatland site in 2002 (continued).

| Scientific Name | Common Name | Type | | Cover (%) | SD |
|---|---|---|---|---|---|
| Spoil | | | | | |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | N | F | 1.42 | 3.37 |
| *Cornus canadensis* L. | Bunchberry | N | F | 1.25 | 2.26 |
| *Calamagrostis canadensis* Michx | Bluejoint/Marsh Reed Grass | N | GSFH | 1.08 | 1.78 |
| *Vaccinium myrtilloides* Michx | Blueberry | N | ST | 0.75 | 1.60 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSFH | 0.50 | 1.17 |
| *Equisetum arvense* L. | Common Horsetail | N | GSFH | 0.42 | 0.79 |
| *Rubus chamaemorus* L. | Cloudberry | N | F | 0.42 | 1.44 |
| *Achillea millefolium* L. | Common Yarrow | N | F | 0.25 | 0.87 |
| *Agrostis scabra* Willd | Tickle Grass | N | GSFH | 0.17 | 0.58 |
| *Epilobium palustre* L. | Marsh Willow Herb | N | F | 0.08 | 0.29 |
| *Festuca* species L. | Unknown Fescue Species | I | GSFH | 0.08 | 0.29 |
| West Forest Fringe | | | | | |
| Moss species | Unknown Moss Species | N | | 11.33 | 13.54 |
| *Carex crawfordii* Fern. | Crawford's Sedge | N | GSFH | 2.33 | 5.26 |
| *Vaccinium myrtilloides* Michx | Blueberry | N | ST | 2.33 | 3.50 |
| *Epilobium angustifolium* L. | Fireweed | N | F | 1.25 | 4.33 |
| *Cornus canadensis* L. | Bunchberry | N | F | 0.75 | 1.77 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSFH | 0.75 | 1.22 |
| *Rubus chamaemorus* L. | Cloudberry | N | F | 0.50 | 1.45 |
| *Carex* species L. | Unknown Sedge Species | N | GSFH | 0.42 | 0.79 |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | N | F | 0.42 | 1.44 |

Table 3.9. Mean cover of plant species by pipeline right-of-way zone of the topographic high treatment in the peatland site in 2002 (continued).

| Scientific Name | Common Name | Type | | Cover (%) | SD |
|---|---|---|---|---|---|
| West Forest Fringe | | | | | |
| *Salix lutea* Nutt. | Yellow Willow | N | ST | 0.33 | 1.16 |
| *Ledum groenlandicum* Oeder | Common Labrador Tea | N | ST | 0.25 | 0.87 |
| *Betula glandulosa* Michx | Bog Birch | N | ST | 0.08 | 0.29 |
| *Gaultheria hispidula* (L.) Bigel. | Creeping Snowberry | N | ST | 0.08 | 0.29 |
| *Vaccinium caespitosum* Michx. | Dwarf Bilberry | N | ST | 0.08 | 0.29 |
| West Forest | | | | | |
| Moss species | Unknown Moss Species | N | | 93.50 | 13.85 |
| *Ledum groenlandicum* Oeder | Common Labrador Tea | N | ST | 40.00 | 32.02 |
| *Vaccinium myrtilloides* Michx | Blueberry | N | ST | 6.33 | 8.02 |
| *Vaccinium vitis-idaea* L. | Bog Cranberry | N | ST | 6.17 | 11.14 |
| *Picea mariana* (Mill.) BSP. | Black Spruce | N | ST | 3.33 | 8.88 |
| *Salix maccalliana* Rowlee | Maccall's Willow | N | ST | 3.33 | 8.88 |
| *Vaccinium uliginosum* L. | Bog Bilberry | N | ST | 0.92 | 1.93 |
| *Rubus chamaemorus* L. | Cloudberry | N | F | 0.83 | 2.89 |
| *Cornus canadensis* L. | Bunchberry | N | F | 0.67 | 1.61 |
| *Gaultheria hispidula* (L.) Bigel. | Creeping Snowberry | N | ST | 0.42 | 1.44 |
| *Petasites palmatus* (Ait.) A. Gray | Palmate Leaved Coltsfoot | N | F | 0.42 | 1.44 |
| *Betula glandulosa* Michx | Bog Birch | N | ST | 0.42 | 1.44 |
| *Equisetum sylvaticum* L. | Woodland Horsetail | N | GSFH | 0.17 | 0.58 |
| *Pyrola* species L. | Unknown Wintergreen | N | F | 0.17 | 0.58 |

N = native, I = introduced, GSFH = grass, sedge, fern or horsetail, ST = shrub or tree, F = forb

N = 84, SD = standard deviation

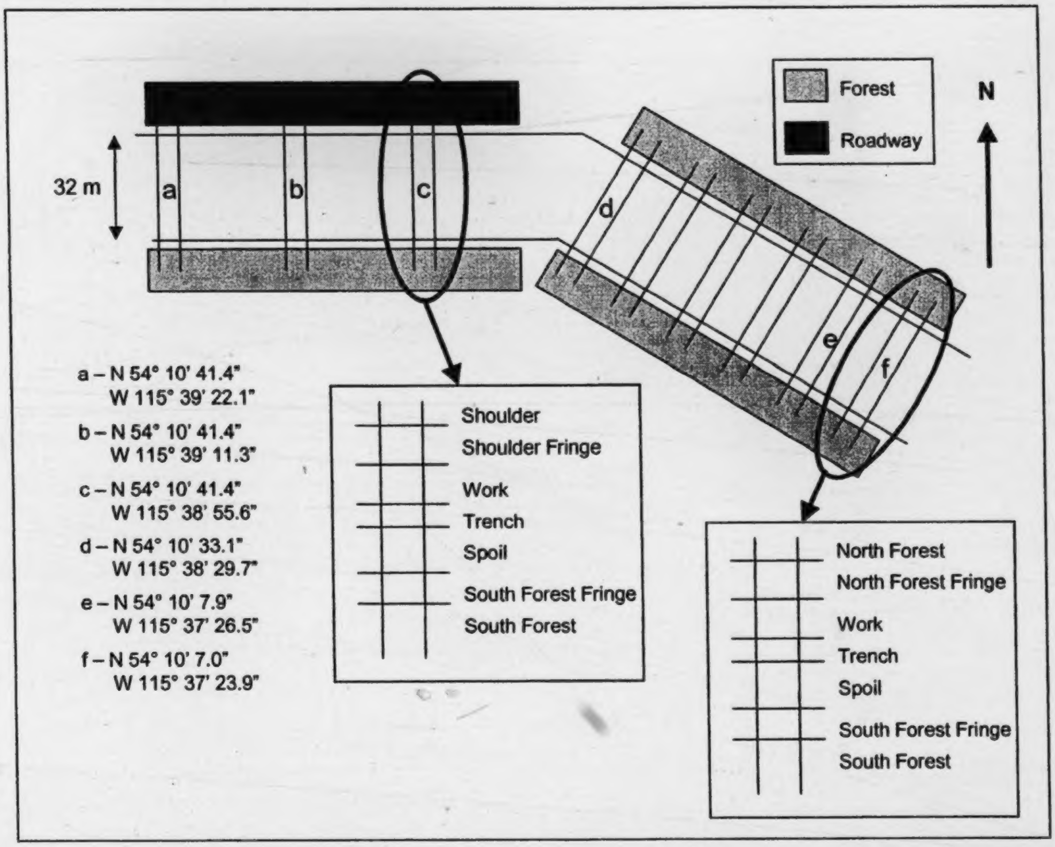
Forest
Roadway
N
32 m
a
b
c
d
e
f
a – N 54° 10' 41.4"
W 115° 39' 22.1"
b – N 54° 10' 41.4"
W 115° 39' 11.3"
c – N 54° 10' 41.4"
W 115° 38' 55.6"
d – N 54° 10' 33.1"
W 115° 38' 29.7"
e – N 54° 10' 7.9"
W 115° 37' 26.5"
f – N 54° 10' 7.0"
W 115° 37' 23.9"
Shoulder
Shoulder Fringe
Work
Trench
Spoil
South Forest Fringe
South Forest
North Forest
North Forest Fringe
Work
Trench
Spoil
South Forest Fringe
South Forest

Figure 3.1. Schematic of mainline pipeline mixedwood forest site. The three blocks adjacent to the roadway are in the seeded treatment and the six blocks with forest on both sides are in the natural recovery treatment. The enlarged blocks show the pipeline right-of-way treatments within the seeded and natural recovery treatments. The letters (a-f) correspond to the center of the trench location within each block.

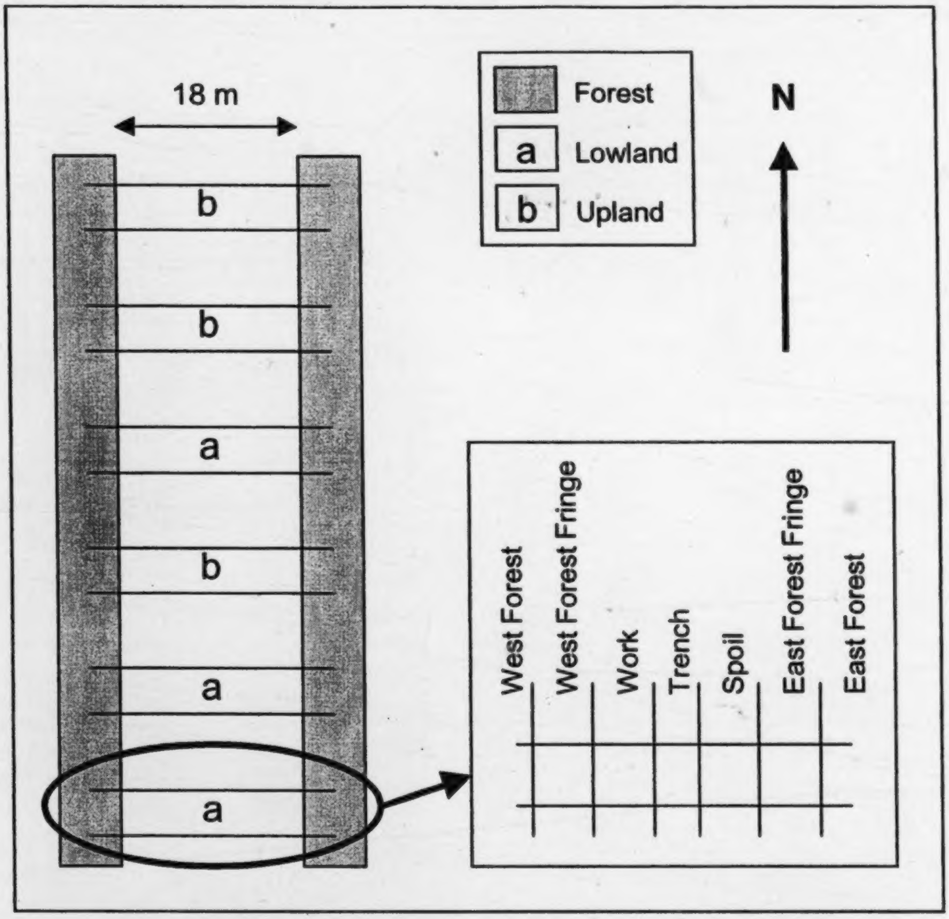
18 m
Forest
a Lowland
b Upland
N
b
b
a
b
a
a
West Forest
West Forest Fringe
Work
Trench
Spoil
East Forest Fringe
East Forest

Figure 3.2. Schematic of lateral pipeline peatland site. Three blocks (a) are topographic lows and three blocks (b) are topographic highs. Blocks were not seeded. The enlarged block shows the pipeline right-of-way treatments.

# IV. SYNTHESIS

## 1. Introduction

The first objective of this research was to compare the effectiveness of natural recovery and seeding on the reclamation of a pipeline right-of-way (RoW) in the central mixedwood subregion of Alberta. It has long been accepted that natural recovery is inappropriate as the amount of bare ground on a site will predispose it to erosion by wind and water. The time to revegetate was also expected to be too lengthy for acceptable reclamation standards.

The second objective of this research was to determine the effect of pipeline installation on soil and vegetation parameters of seeded and natural recovery sites. The various zones of the RoW were expected to have different effects on soil and vegetation parameters due to the construction activities on these zones.

Vegetation parameters were measured in summer 2002 and included ground cover characteristics (live cover, litter and bare ground) and plant community composition. Soil parameters were measured in summers 2002 and 2003 and included physical (bulk density, penetration resistance and particle size distribution) and chemical (nutrients, pH, electrical conductivity and total organic carbon) components.

## 2. Results and Practical Applications

The paramount finding of this study was that after two seasons of growth, ground cover was not biologically different between the seeded and natural recovery treatments. Both the seeded and natural recovery treatments had over 40% live cover. The bare ground on the natural recovery treatment was approximately 12% higher than the seeded treatment but this did not translate into any visible erosion. The higher bare ground of the natural recovery was a result of the lower litter, resulting from the lower litter producing capacity of plants on natural recovery compared to seeded treatments. A potential solution to this would be to plant an annual cover crop so that the organic litter layer is built more rapidly.

The economical benefit of this method is apparent. In 2000, the seed mix applied cost approximately \$ 22 kg$^{-1}$. At a rate of 14 kg ha$^{-1}$, that translates to \$315 ha$^{-1}$ or \$1009 km$^{-1}$.

Additional benefits provided by natural recovery included greater plant species richness and fewer invasive or weedy species. The pipeline installation and resulting RoW zones did not have a statistically significant effect on the vegetation parameters. Trenching on the RoW often results in reduced vegetation because of compaction at the surface, admixing from B and C horizons and a greater removal of vegetation and plant propagules prior to construction. This study found that the highest level of cover was on the trench in the seeded and natural recovery treatments.

Biologically significant differences were not expected between seeded and natural recovery soil parameters since soil handling practices were meant to be consistent between treatments. Subtle differences in vegetation across the disturbed areas are not likely to affect most of the soil parameters measured. Vegetation could have influenced organic matter content and some of the soil nutrient measurements but it is unlikely they would be exerting much effect on the soil physical parameters measured. Had differences been found between the two treatments one could have concluded that soil handling procedures were not consistent during construction. Pipeline installation did not have a statistically significant effect on organic matter, pH or bulk density on the seeded and natural recovery treatments.

The only parameter that appeared to change at an influential level was clay content. Although there was not a difference between the vegetation treatments, there were differences across RoW treatments of each vegetation treatment. The trench had the highest level of clay increase in the 0 to 10 cm depth on both vegetation treatments. The increase in clay was only slightly more than that seen on the spoil treatment. It was interesting to see that the increase in clay was not pronounced on the work treatments indicating that the spoil material was properly placed and then returned to the trench. The clay added to the surface soil through admixing may actually have improved soil quality. The addition of the clay to the upper soil horizon, which is normally depleted of clay by eluviation in this area of the province, may improve the soil by increasing the cation exchange capacity and increasing the water holding potential.

This research indicates that natural recovery may be an excellent method of reclaiming pipeline disturbances in the central mixedwood region of Alberta. This is a strong indication that current pipeline reclamation practices are sufficient to support natural recovery provided the local environmental conditions are conducive. In this study, the cover level achieved after two years of growth by natural recovery was the same as the seeded treatment, although this may not always be the case.

Time for acceptable reclamation to be reached will need to be addressed in reclamation criteria if natural recovery is accepted as a suitable technique. Under drier conditions or on different shaped disturbances that do not foster invasion and egression of desired species, the time needed for cover to develop on a natural recovery site may be greater than that on a seeded site. This appears to be a good compromise, considering all of the other positive results associated with natural recovery, specifically, the increased plant diversity, closer resemblance to the native community and fewer weedy species.

## 3. Future Research

Despite all of the positive findings from this research regarding natural recovery, there are many questions that remain to be answered. The area where this research was done had many environmental conditions that undoubtedly contributed to its success. The terrain was quite flat which mitigated any erosion potential that may occur in other settings. The forest setting and salvage of the duff material provided a good seed source which may not be available at all sites. The timely precipitation events can not be counted on in all areas of the province. It may not be an exaggeration to say that this research was done in one of the areas in the province where success is most likely. However, the conclusion from this study was that natural recovery was a success on this section of pipeline in this part of the province. The plant community that developed did so quickly and more closely resembled adjacent native conditions than did the seeded section. It now appears that the next step is not to determine if natural recovery works but rather where it works and on what type of disturbance it may be successful.